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Mr. Jack Bush
Special Projects and Plans
703-697-2928
DSN 227-2928

FINAL ENVIRONMENTAL PLANNING
TECHNICAL REPORT

GEOLOGIC RESOURCES

January 1984

PREFACE

The President has directed that the Air Force deploy the Peacekeeper missile system at a location near F.E. Warren Air Force Base (hereafter F.E. Warren AFB), close to Cheyenne, Wyoming. The Peacekeeper system (formerly known as the M-X system) is an advanced, land-based intercontinental ballistic missile. The plan calls for the replacement of 100 existing Minuteman III missiles with 100 Peacekeeper missiles. Existing missile silos will be used, and there will be very little structural modification needed. Missile replacement will occur within the 319th and 400th Strategic Missile Squadrons, the two squadrons (50 missiles each) located nearest F.E. Warren AFB. Peacekeeper deployment will occur between 1984 and 1989.

An environmental impact statement (EIS) was prepared for the Proposed Action as outlined above. Information contained in the EIS is based upon environmental information and analysis developed and reported in a series of 13 final environmental planning technical reports (EPTRs). This volume is one of those reports. The 13 resource areas are:

- Socioeconomics (employment demand, housing, public finance, construction resources, and social well-being);
- Public Services and Facilities;
- Utilities;
- Energy Resources;
- Transportation;
- Land Use (land use, recreation, and visual resources);
- Cultural and Paleontological Resources;
- Water Resources;
- Biological Resources;
- Geologic Resources;
- Noise;
- Air Quality;
- Jurisdictional.

CONTENTS

CONTENTS (Continued)

Page

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0

INTRODUCTION

1.0 INTRODUCTION

This final environmental planning technical report (EPTR) is a companion document to the geologic resources section of the final environmental impact statement (FEIS) for the Peacekeeper in Minuteman Silos project. It provides data, methodologies, and analyses which supplement and extend those presented in the FEIS.

This final EPTR consists of six major sections and an appendix. Section 1.0 provides an overview of the Peacekeeper in Minuteman Silos project and a description of geologic resources and their elements.

Section 2.0 presents a detailed description of the environment potentially affected by the project. It includes a capsule description of the environmental setting (Section 2.1) and project requirements (Section 2.2). Section 2.3 defines the Region of Influence and Areas of Concentrated Study for the resource. Section 2.4 (Derivation of Data Base) follows with a discussion of the literature sources, group and agency contacts, and primary data which provide the data base for the report. Section 2.5 describes analytic methods used to determine existing environmental conditions in the Region of Influence. Detailed analyses of the existing environment, broken down by constituent elements of the resource, follow in Section 2.6.

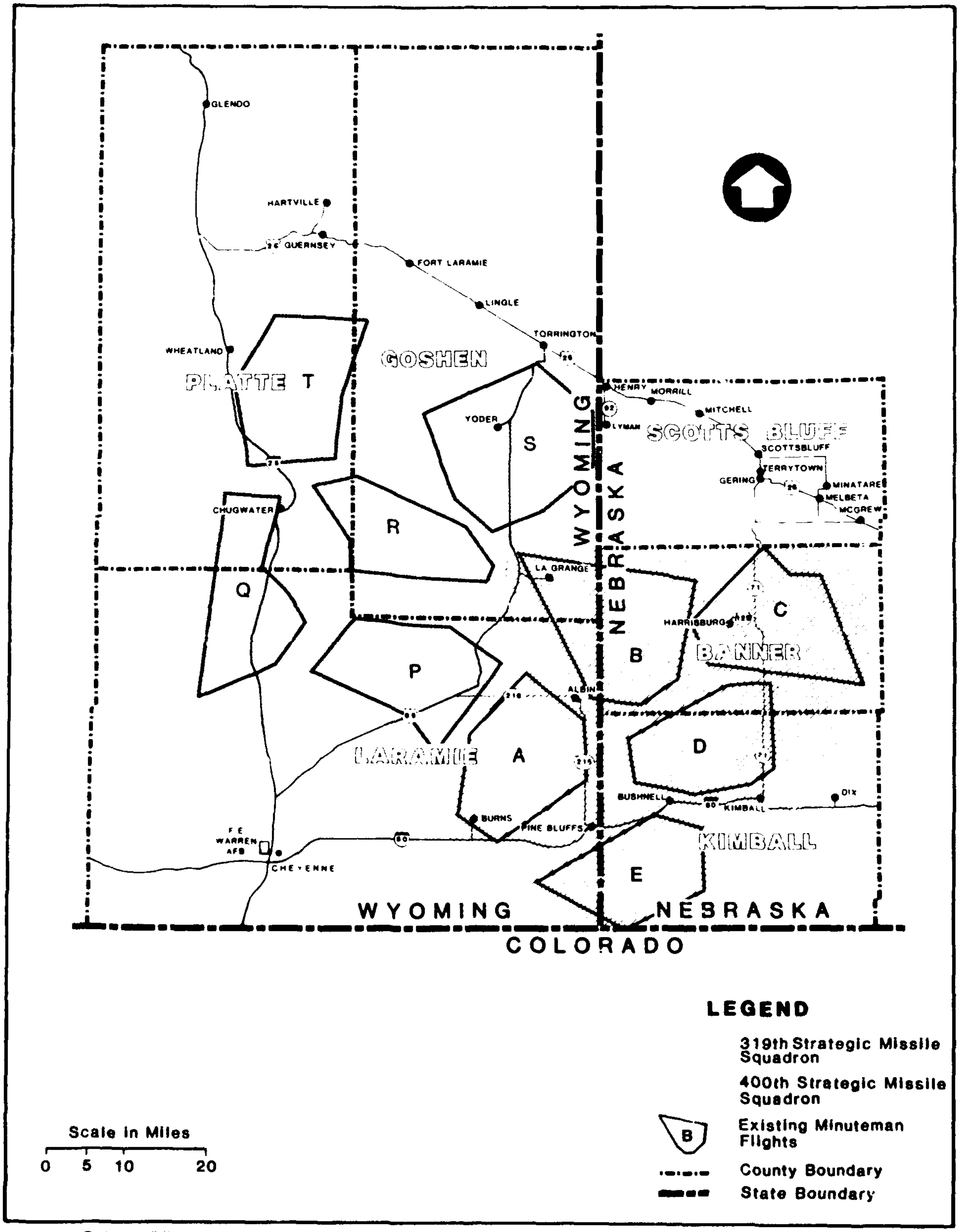
Section 3.0 describes environmental consequences of the Proposed Action and its project element alternatives, the No Action Alternative, mitigation measures, and unavoidable impacts. It contains detailed definitions of each potential level of impact (negligible, low, moderate, and high) for both short-term and long-term impacts. Beneficial effects are also discussed. Definitions of significance are also included. Methods used for analyzing future baseline and project impacts are described, as are assumptions and assumed mitigations. Additional mitigation measures to reduce project impacts are also described.

Sections 4.0 (Glossary), 5.0 (References), 6.0 (List of Preparers), and Appendix A (Soil Erosion Assessment) conclude the EPTR.

1.1 Peacekeeper in Minuteman Silos

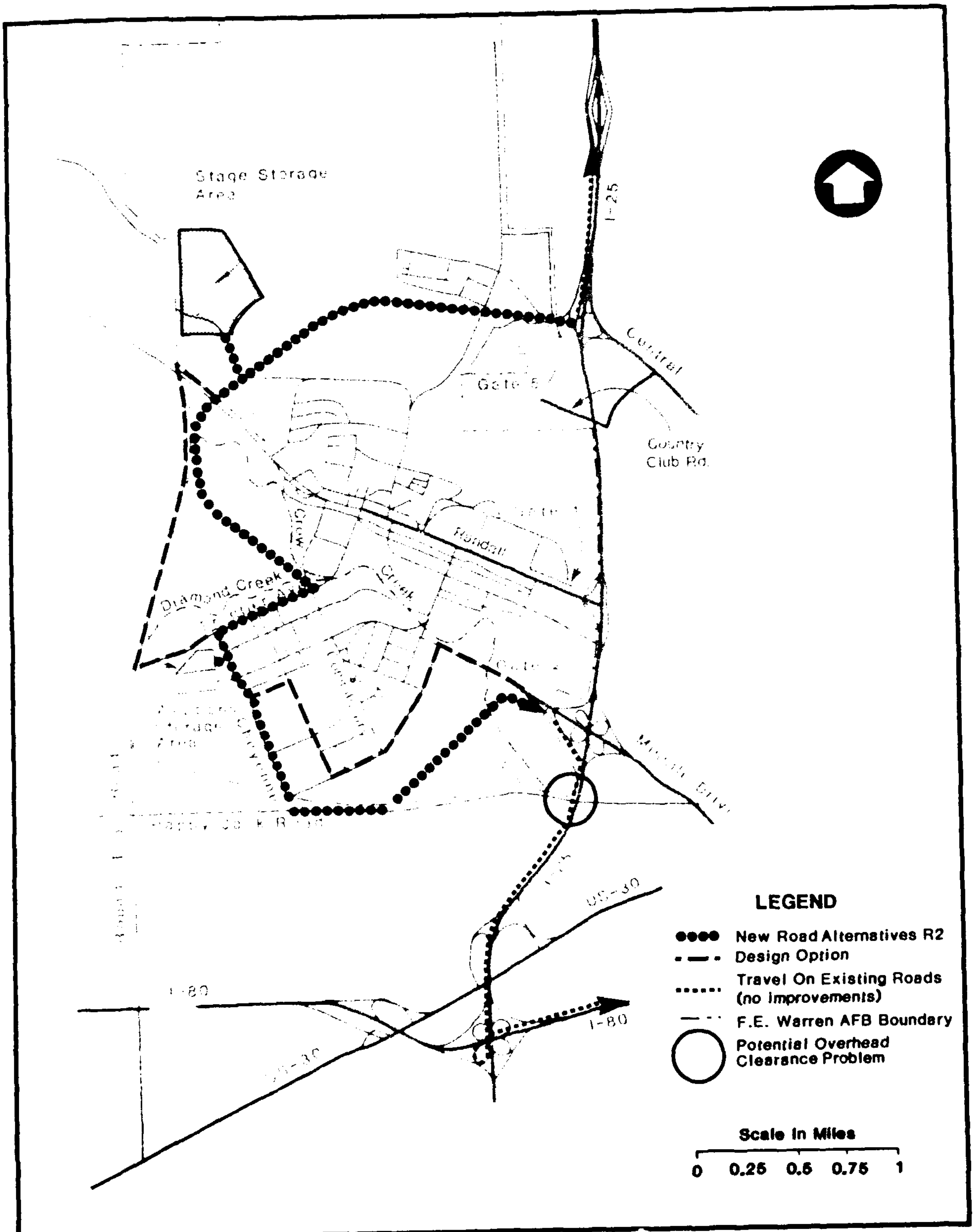
The Peacekeeper system, which the Air Force plans to deploy within the 90th Strategic Missile Wing at F.E. Warren Air Force Base (AFB), Wyoming, is an advanced land-based intercontinental ballistic missile system designed to improve the nation's strategic deterrent force. Deployment of the Peacekeeper calls for replacement of 100 existing Minuteman III missiles with 100 Peacekeeper missiles. Missile replacement will occur in the 319th and 400th Strategic Missile Squadrons, located nearest F.E. Warren AFB (Figure 1.1-1). The Deployment Area covers parts of southeastern Wyoming and the southwestern Nebraska Panhandle.

Construction at F.E. Warren AFB will occur between 1984 and 1986. Fourteen new buildings will be constructed, and modifications or additions will be made to 11 existing buildings. Approximately 400,000 square feet of floor space will be built or modified. A new road configuration, to be selected from three alternatives, is proposed to link Peacekeeper facilities onbase and to provide improved access to or from the base (Figures 1.1-2, 1.1-3, and 1.1-4).



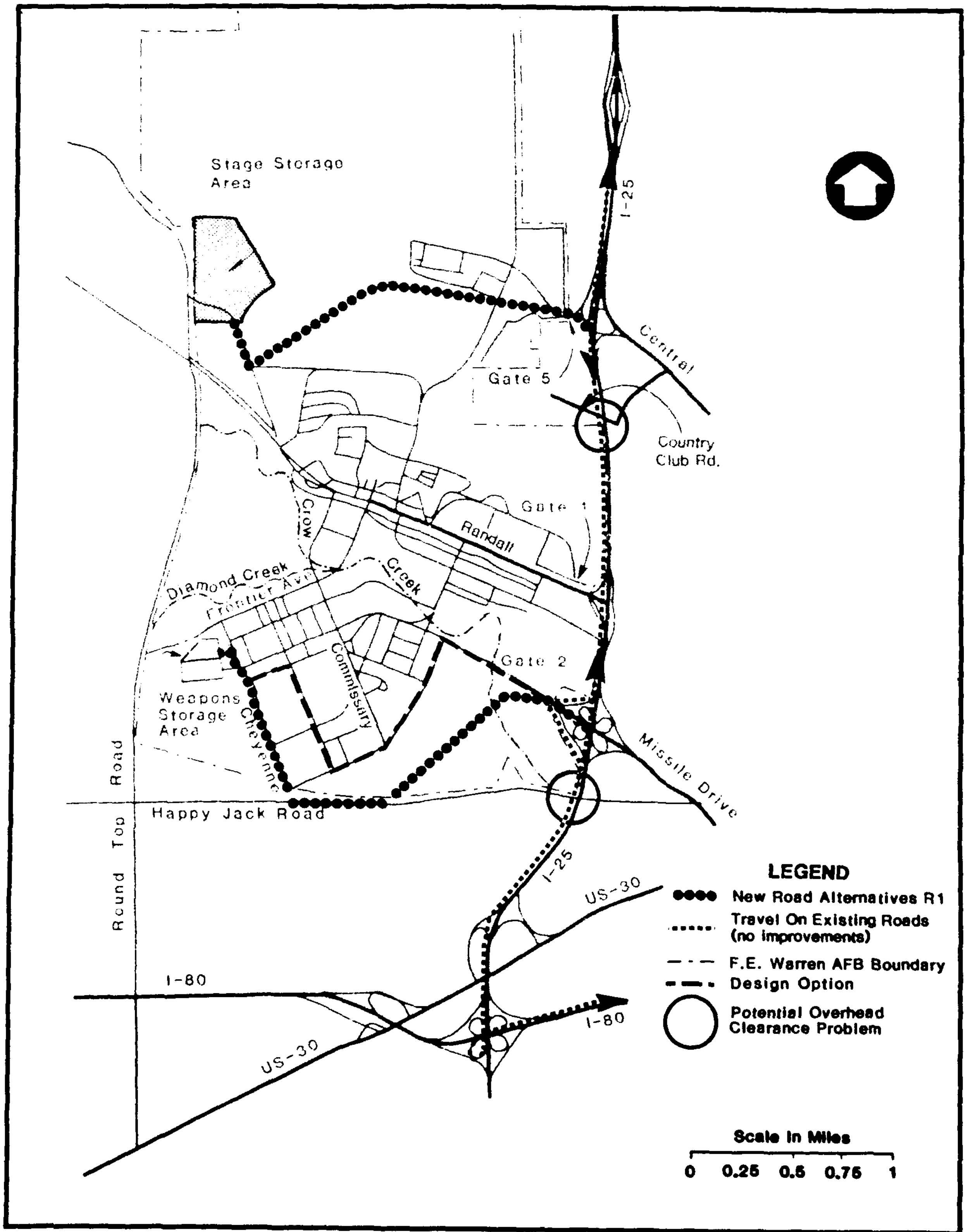
PEACEKEEPER DEPLOYMENT AREA

FIGURE NO. 1.1-1



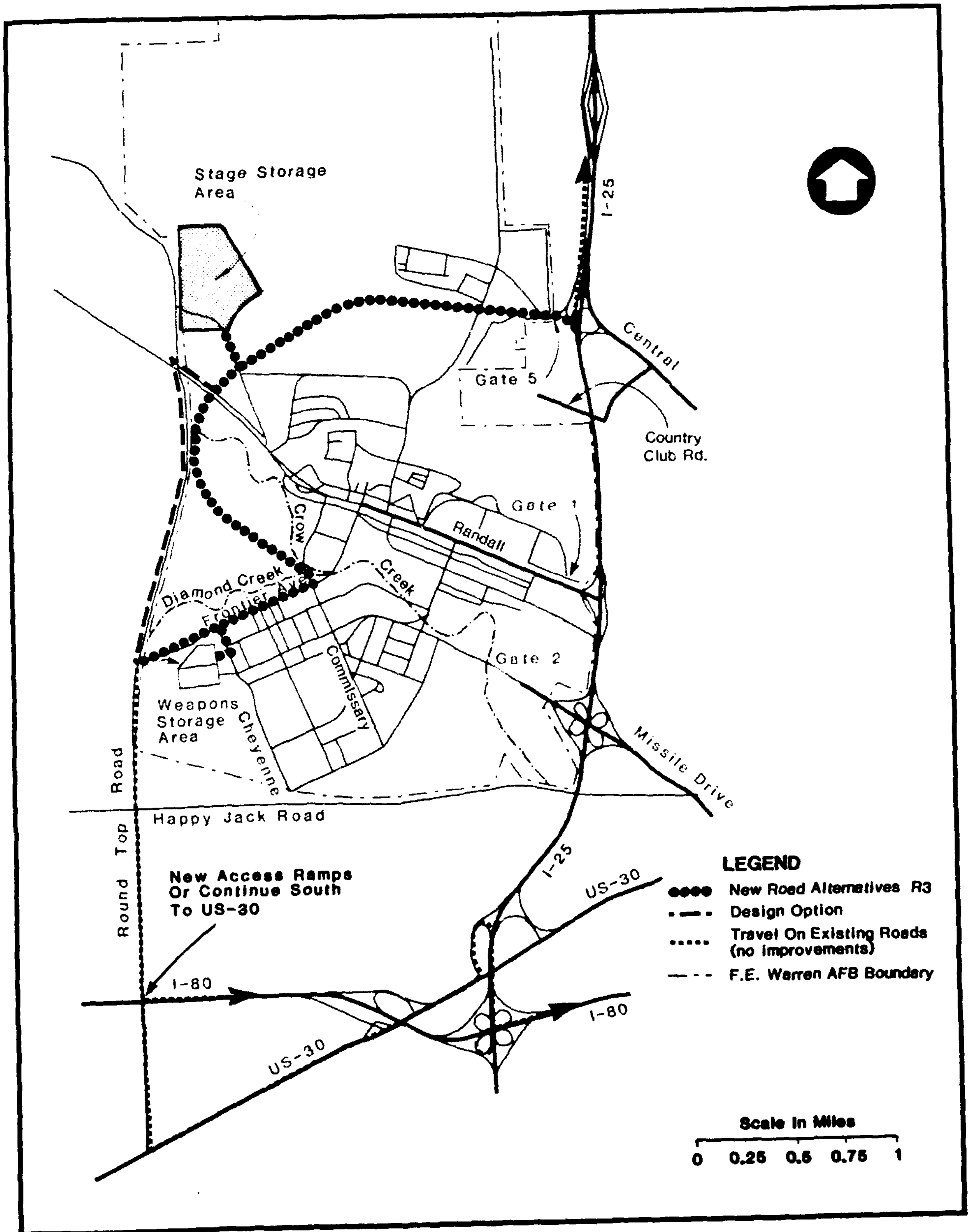
NEW ROADS AT F.E. WARREN AFB:
PROPOSED ACTION R2

FIGURE NO.
1.1-2



NEW ROADS AT F.E. WARREN AFB: ALTERNATIVE R1

FIGURE NO. 1.1-3



NEW ROADS AT F.E. WARREN AFB: ALTERNATIVE: R3

FIGURE NO. 1.1-4

Work in the Deployment Area will take place between 1985 and 1989. Many of the access roads to the Launch Facilities will be upgraded. Bridge clearance problems will be corrected, and some culverts and bridges may need to be upgraded. Below-ground modifications will be related to removal of Minuteman support hardware, insertion of a protective canister to enclose the Peacekeeper, and installation of communications systems and support equipment.

A total of 11 alternatives have been chosen as candidate routes for communication connectivity between Squadrons 319 and 400 (Figure 1.1-5). Five routes will be selected for installation. Total buried cable length will range from approximately 82 to 110 miles, depending upon final route selections.

Under the Proposed Action two dispatch stations would be established, one each in the northern and eastern portions of the Deployment Area. Although actual locations have not been selected, Chugwater, Wyoming and Kimball, Nebraska are representative locations analyzed in the Final Environmental Impact Statement and in this EPTR. Dispatch stations would be not more than 5 acres in size and would be used for the temporary open storage of equipment and material. One or more buildings would also be present at each site for contractor use as office space. All dispatch stations would be removed prior to project completion. In addition to the Proposed Action, two alternatives are considered in this environmental impact assessment:

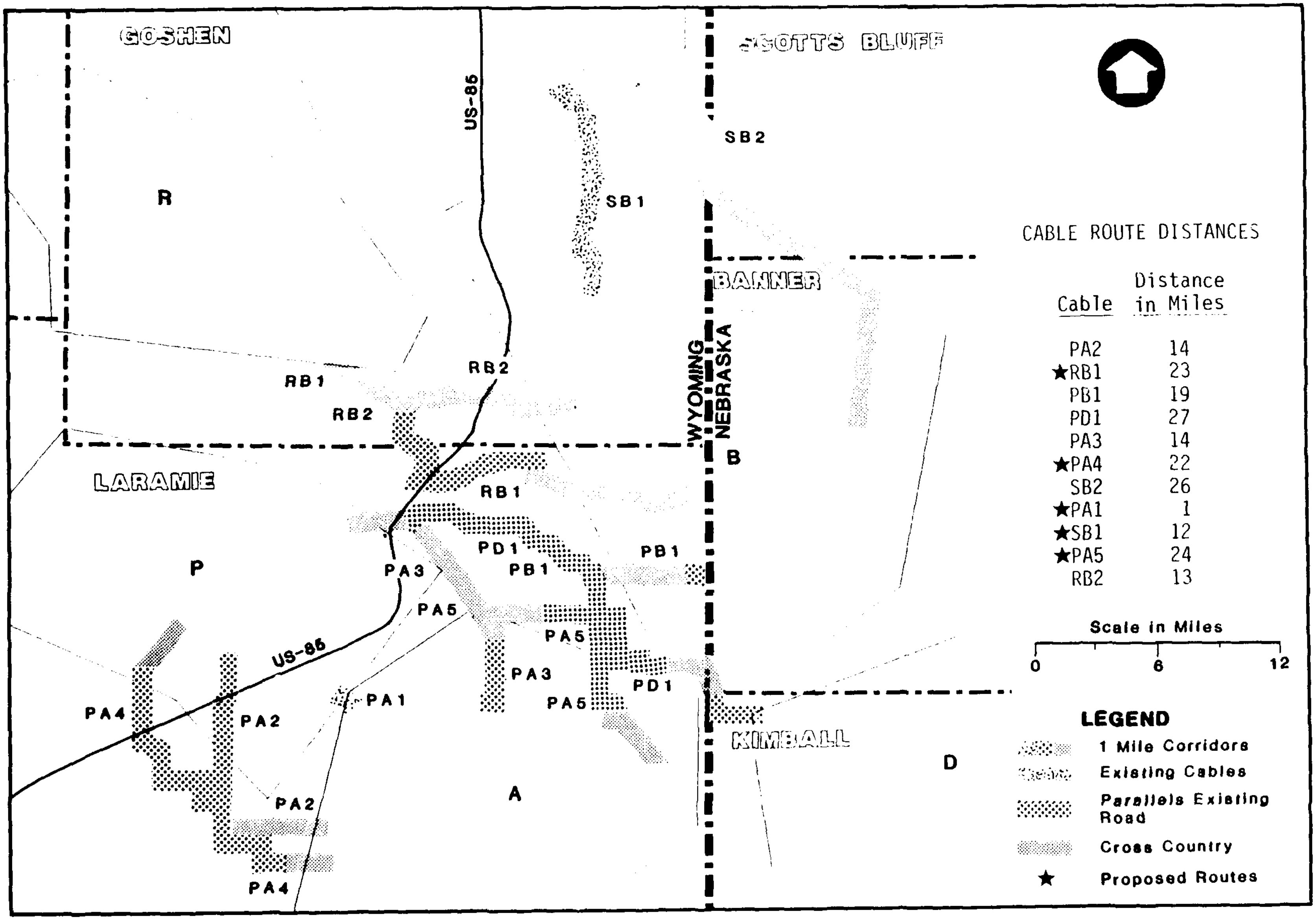
1) One dispatch station only, in the eastern part of the Deployment Area; or

2) No dispatch stations.

Two options have been identified for resurfacing Deployment Area roads. Surfacing Option A involves gravel upgrades of 252 miles of existing gravel roads and the paving or repaving of 390 additional miles of gravel and asphalt roads. Surfacing Option B involves the paving or repaving of all 642 miles of gravel and asphalt roads listed in Surfacing Option A.

Direct manpower for construction, assembly and checkout, and operation of the system will peak during 1986 when an average of nearly 1,600 persons will be required. In 1991, following deployment, the remaining increased operational workforce at F.E. Warren AFB will consist of about 475 persons. Table 1.1-1 presents the average annual workforce, based on quarterly estimates for each year of construction.

Table 1.1-2 shows the average number of jobs including those which are considered to be filled by available labor; as well as those filled by weekly commuters and inmigrants, on an annual average basis. In general, locally available labor will fill all the road and construction jobs.



ALTERNATIVE CABLE ROUTES

FIGURE 1.1-5

Table 1.1-1

PROJECT AVERAGE MANPOWER REQUIREMENTS BY YEAR[1]

	1984	1985	1986	1987	1988	1989	1990	1991
Deployment Area								
Construction	5	40	60	60	40	0	0	0
Assembly and Checkout	0	15	210	285	265	265	10	0
Operations	0	0	0	0	0	0	0	0
Defense Access Road	0	275	315	150	0	0	0	0
Subtotal	5	330	585	495	305	265	10	0
Operating Base								
Construction	100	630	70	0	0	0	0	0
Assembly and Checkout	40	130	525	555	515	510	22	0
Operations	0	130	415	490	500	500	475	475
Subtotal	140	890	1,010	1,045	1,015	1,010	497	475
TOTAL:	145	1,220	1,595	1,540	1,320	1,275	507	475

Note: [1] Estimates based on average quarterly employment.

Table 1.1-2

TOTAL JOBS, LOCAL AND REGIONAL HIRES, AND INMIGRATION FOR THE EMPLOYMENT DEMAND REGION OF INFLUENCE

	1984	1985	1986	1987	1988	1989	1990	1991 and beyond
1) Total (Direct/ Indirect) Additional Jobs	250	2,400	2,675	2,550	2,025	1,825	650	590
2) Average Annual Local Hires	157	1,750	1,525	1,350	1,100	815	225	230
3) Average Annual Weekly Commuters	25	225	175	100	25	10	0	0
4) Average Annual Inmigrant Workers	75	425	950	1,100	925	1,000	425	360
5) Unsuccessful Job-Seekers	30	185	180	150	165	110	70	0
6) Inmigrant[1] Population	275	1,475	2,875	3,200	3,025	2,875	1,200	925

Note: [1] Includes inmigrants, workers, and unsuccessful job-seekers.

As a result of the purchase of materials in the project area and the local expenditures of project employees, additional jobs will be created in the region. These jobs are estimated to number as follows:

Year:	1984	1985	1986	1987	1988	1989	1990	1991 & on
Indirect Jobs:	105	1,180	1,080	1,010	705	550	143	115

Estimated materials and costs for the project, based on total project budgetary considerations, are shown by Standard Industrial Classification in Table 1.1-3.

A number of construction and support materials will be obtained from sources within the project area. Among the materials exerting a major influence on assessment of project impacts are aggregate (4.6 million tons), water (516 acre-feet), fuel (7.6 million gallons), and electricity (3.8 million kWh). In the case of water supply for construction, the Air Force will identify and, if necessary, obtain permits for the water or purchase existing water rights.

1.2 Description of the Resource

For this study, geologic resources include geologic hazards, energy and mineral resources, and soil resources. The existing geologic environment in southeastern Wyoming and western Nebraska is described and the geologic resources potentially affected by the implementation of the Peacekeeper in Minuteman Silos project are studied and analyzed.

Table 1.1-3

ESTIMATED MATERIAL REQUIREMENTS
BY STANDARD INDUSTRIAL CLASSIFICATION

Industrial Classification	Estimated 1982 Dollars (1,000s)
Fabricated Structural Metal	$22,999
Unclassified Professional Services and Products	14,358
Cement and Concrete Products	10,862
General Wholesale Trade	8,890
Structural Metal Products[1]	11,983
Millwork, Plywood, and Wood Products[1]	3,941
Copper, Copper Products	3,902
Electrical Lighting and Wiring	3,871
Stone and Clay Mining and Quarrying	39,728
Stone and Clay Products[1]	2,955
Basic Steel Products	1,233
Heating and Air Conditioning Apparatus	1,525
Plumbing and Plumbing Fixtures	938
Petroleum Refining and Products	5,148
Material Handling Equipment	1,970
Sawmills and Planing Mills	1,478
Paints and Allied Products	1,478
Plastic Products[1]	1,478
Furniture and Fixtures	986
Structural Clay Products	986
General Hardware	986
Scientific Instruments	986
Rail Transport	986
Real Estate	986
Construction, Mining, and Oilfield Machinery	749
TOTAL:	$145,402

Note: [1] Not included in other Industrial Classifications.

2.0

AFFECTED ENVIRONMENT

2.0 AFFECTED ENVIRONMENT

2.1 General

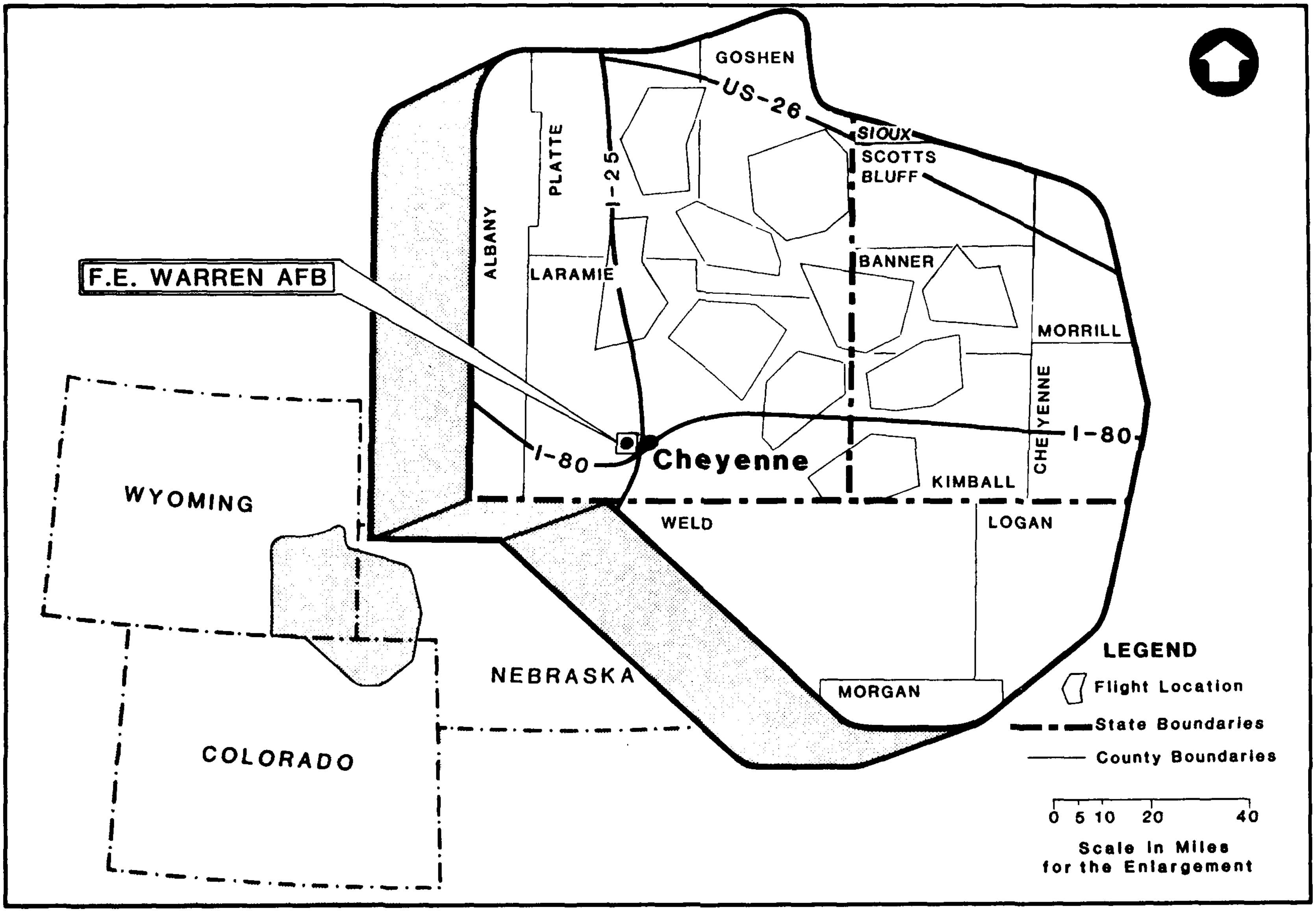
The Deployment Area (DA) is located in the Great Plains of the west-central United States. In general, this area is characterized by vast expanses of gently rolling rangeland, periodically interrupted by stream drainages. The major drainage is to the east through the North and South Platte rivers and their main tributaries. Stratigraphic units exposed throughout the DA are predominantly Tertiary and Quaternary sedimentary rocks and sediments, ranging from sandstone and siltstone to gravels and sands. The underlying stratigraphic sequence consists of thousands of feet of sedimentary units, partially warped along the northern trend of the Denver-Julesburg Basin, a large, asymmetrical basin underlying most of eastern Colorado and smaller portions of southeastern Wyoming and western Nebraska.

2.2 Project Requirements

Overall project requirements are outlined in Section 1.1. The only direct geologic resources project requirement anticipated for the deployment scheme is a demand for aggregate for construction. Preliminary estimates of sand and gravel requirements are about 4.6 million tons or approximately 2.6 million cubic yards (cy).

2.3 Region of Influence

The overall Region of Influence (ROI) for geologic resources includes all of Laramie County, Wyoming; Kimball and Banner counties, Nebraska; portions of Albany, Platte, and Goshen counties, Wyoming; portions of Cheyenne, Morrill, Scotts Bluff, and Sioux counties, Nebraska; and portions of Logan, Morgan, and Weld counties, Colorado (Figure 2.3-1). The ROI is an irregularly shaped area bounded on the north by an east-west line from the divide of the Laramie Range to Guernsey, Wyoming, then northeastward to Rawhide Creek near Jay Em, Wyoming, then south to the northern extent of the valley of the North Platte River, then southeastward to near Bridgeport, Nebraska. The eastern boundary is formed by a north-south line extending from the North Platte River near Bridgeport, south to Sidney, Nebraska, primarily along Highway 385, and then south and southwest from Sidney along Road 113 to the southern extent of the valley of the South Platte River. The southern boundary follows westward along the southern extent of the South Platte River Valley to Goodrich, Colorado, then in a straight line northwestward to the intersection of Interstate 25 and the Colorado-Wyoming state line. It then continues westward along the state boundary and terminates at the divide of the Laramie Range. The nearly north-south trending western boundary is delineated by the divide of the Laramie Range. This large ROI is defined primarily for energy and mineral resources, and specifically for aggregate resources, and is also applicable to geologic hazards. Smaller Areas of Concentrated Study (ACSs) are defined specifically for faulting investigations and soil resources.



REGION OF INFLUENCE FOR
GEOLOGIC RESOURCES

FIGURE NO. 2.3-1

2.3.1 Geologic Hazards

2.3.1.1 Definition

The ROI for geologic hazards is defined to include those areas in which implementation and operation of the project may be affected by naturally occurring geologic phenomena, or project activities may accelerate or initiate geologic processes. The ROI for geologic hazards coincides with the overall ROI for geologic resources because of regional seismicity. Other geologic hazards are addressed according to site-specific locations or ACSs.

2.3.1.2 Justification

Normally, the ROI for geologic hazards is smaller than the one used for energy and mineral resources because considerations of geologic hazards are often site specific, i.e., individual landslides, etc. Since regional seismicity can impact a broad area, the ROI for geologic hazards was expanded to coincide with the overall ROI. Faulting was studied throughout the ROI, and the Wheatland-Whalen Fault System has been identified as an ACS because of its potential importance to the project.

2.3.2 Energy and Mineral Resources

2.3.2.1 Definition

The ROI for energy and mineral resources, specifically aggregate, coincides with and is the basis for the overall geologic resources ROI. All other elements of energy and mineral resources are addressed according to specific locations.

2.3.2.2 Justification

The ROI for energy and mineral resources, specifically aggregate, encompasses known regional sources of aggregate and areas likely to serve as additional sources if needed. These areas lie within economic haul distances to the potential construction sites and include specific pit and quarry locations. Because the silo locations have already been established, any project effect on other energy and mineral resources will only involve specific locations directly disturbed by the project.

2.3.3 Soil Resources

2.3.3.1 Definition

The ROI for soil resources is restricted to ACSs such as construction sites and support areas directly disturbed by the project (construction at F.E. Warren AFB, along the affected access roads, and the communication cable routes between Flights).

2.3.3.2 Justification

These ACSs are justified because of the direct relationship between specific construction locations and areas of likely soil disturbance. Ground disturbance is expected to be confined to narrow corridors for roads, cable routes, and construction at F.E. Warren AFB.

2.4 Derivation of Data Base

2.4.1 Literature Sources

The major literature sources used in developing the profile of existing geologic resources include:

- United States Geological Survey (USGS);
- United States Bureau of Mines (USBM);
- Wyoming Oil and Gas Conservation Commission;
- Nebraska Oil and Gas Conservation Commission;
- United States Department of Agriculture (USDA), Soil Conservation Service (SCS);
- Conservation and Survey Division, Institute of Agriculture and Natural Resources, the University of Nebraska - Lincoln;
- Geological Survey of Wyoming;
- Nebraska Department of Roads;
- Wyoming Highway Department; and
- Colorado Geological Survey.

Specific references from these information sources are cited throughout the text in Section 2.6 and are detailed in Section 5.0, References Cited and Reviewed.

2.4.2 Groups and Agency Contacts

The following are state and county groups and agencies contacted to gather input and suggestions for this project.

- Geological Survey of Wyoming;
- Wyoming Oil and Gas Conservation Commission;
- Wyoming State Engineer's Office;
- Wyoming Office of the SCS;
- Wyoming Highway Department;
- University of Nebraska, Conservation and Survey Division;
- Nebraska Oil and Gas Conservation Commission;
- Nebraska Office of the SCS;

- Nebraska Department of Roads; and
- State Offices of the USGS.

2.4.3 Primary Data

Primary data collected for this study include:

- Energy and Mineral Resources Map with technical report;
- Preliminary Field Investigations Report - MX Closely Spaced Basing;
- Regional Aggregate Resources Evaluation, F.E. Warren AFB Candidate Suitable Area, Wyoming;
- Working Paper Draft on the Potential for Earthquakes and Surface Faulting on the Wheatland-Whalen Fault System, Southeastern Wyoming; and
- Construction Materials Survey (Phase II), Peacekeeper Facilities, Cheyenne, Wyoming Area.

2.5 Analytic Methods

This section describes analytic methods that were employed to conduct baseline environmental studies.

The collection of geologic data on physiography, stratigraphy, and structural geology serves two functions within an environmental analysis:

- The data provide detailed information for specific analyses of tectonics and a number of geologic hazards that occur on a regional scale (faulting, subsidence, etc.); and
- The data provide the detailed base required by the geological elements for their specific analyses. Examples include physiographic input to the analysis of water and wind erosion of soils, stratigraphic input to aggregate resources, and tectonics input to seismologic and earthquake analyses.

Most of the data collection and analytic methods described in this section serve the second of these functions. Direct applications to models or formulae are reserved for later sections (for example, the soil erosion analysis). The general nature of the data coupled with the numerous variables throughout the region (i.e., differing geologic conditions, nature and life of the project, and sensitivity of specific issues) pose too many differing combinations to be meaningfully applied to any single model.

The approach employed in this study is to evaluate two fundamental relationships:

- The effect of the areal geology (physiography, stratigraphy, and structure) on the project; and

- The effect of the project on the geologic resources pertinent to environmental concerns.

Evaluating the first of these requires more than building a data base; it is essentially a search for broad-scale geologic hazards and an assessment of those hazards and how they relate to the safety of the project.

The second relationship pertains to the potential short and long-term impacts of project development on the geologic environment. Specific impacts usually fall within the categories of geologic hazards, soil erosion, etc., because little overall impact can be identified from project activities relative to physiography, stratigraphy, or structure within any reasonable time frame.

The steps used in gathering and analyzing the geologic data are part of a routine procedure frequently applied to geoenvironmental studies:

- Initial data gathering and preliminary assessment of geologic characteristics;
- Developing criteria for the important geologic characteristics and identifying the most sensitive issues;
- In-depth gathering of published and unpublished data and obtaining interviews with knowledgeable local experts;
- Data reduction to maps, overlays, tables, and matrices; and
- Analysis and prioritization of the most sensitive issues.

2.5.1 Geologic Hazards

Baseline data on potential geologic hazards (regional seismicity, faulting, ground subsidence, landslides, etc.) have been obtained and analyzed within the ROI (Section 2.6.2). In many instances, review of the baseline data was sufficient to preclude specific geologic hazards, i.e., landsliding, subsidence, and liquefaction from further detailed analysis. Based on these data, previous Peacekeeper studies, information from the Intergovernmental Environmental Resource Workshops held in Cheyenne, specific site locations, and professional judgment, the geologic hazards presently considered important are regional seismicity and faulting. However, the hazard from seismicity and faulting represents an impact of the resource on the project and not the project on the resource, and is therefore not discussed as an impact issue in Section 3.0 of this report. The potential effects of the resource on the project are presented as safety issues in Section 1.6.10.4.3 of the Final Environmental Impact Statement (FEIS).

2.5.1.1 Regional Seismicity

There are two principal approaches to the appraisal of seismic risk: probabilistic and deterministic. Probabilistic methods are based primarily on the historical occurrence of earthquakes combined with data on geologic and tectonic past and present conditions. Their reliability is dependent on tectonic forces remaining the same for the period being predicted. If, for example, seismic risk is computed for very long periods of time (e.g., tens of thousands of years for certain waste disposal problems), the length of earthquake history might be small compared to the term for which the risk values are calculated. As a result, the value, reliability, and accuracy of such a probabilistic analysis may be very limited. However, for a facility which would be underground and partly hardened against vibrations and have a design life of less than 50 years (such as this project), a 50 to 100-year earthquake record combined with an understanding of the geologic and tectonic history and an accurate description of the present geologic environment provide a reasonable basis for determining seismic risk.

Deterministic methods traditionally have been used where the upper limit of seismic risk is desired. The deterministic method is usually based on determining activity and seismic potential of faults close enough to affect a potential site. In the case of high-risk nuclear reactors and terminal radioactive waste storage facilities, a fault is considered active if it shows movement of a recurring nature within the last 500,000 years, or any movement within the last 35,000 years (NRC 1975). For more conventional facilities (dams, commercial facilities, etc.), the age criteria for active faults is typically less stringent and often related to the Holocene (i.e., fault movement within the last 10,000 years). Based on these criteria, an active fault is assumed capable of generating an earthquake whether or not there exists associated historic seismicity. The length of the fault is then compared to other faults worldwide of similar length or to larger faults near plate boundaries whose length of rupture is near that of the fault in question. Usually there is little regard for differing tectonic regimes in the region of concern and the region(s) from which fault rupture lengths and associated magnitudes are taken for comparison.

The probabilistic approach to seismic risk was selected as being most appropriate for this project. Based on National Earthquake Information Service (NEIS) data (NEIS 1982, 1983), the DA is an area of low seismicity and relatively high tectonic stability. Earthquakes have not reached damaging levels during historical times and known faults are not associated with tectonic plate boundaries. Seismicity does not appear in lineations suggestive of hidden major faulting. Reported fault offsets in the region dated at less than 10,000 years are very limited geographically. The nominal life of the project structures is understood to be less than 50 years. Therefore, the deterministic method does not appear appropriate for this study. Consequently, probabilistic studies of the region have yielded design accelerations considered conservative for underground structures that have been designed to withstand a nuclear attack.

Several elements of a probabilistic risk assessment require professional judgment. They are:

- The boundaries of seismic source zones;
- The maximum magnitude earthquake possible within each source zone; and
- The formula for the attenuation of the seismic shaking.

In relatively aseismic areas such as eastern Wyoming and western Nebraska, variations in the above parameters have shown little effect on design acceleration.

For this study the seismologic analysis has involved the following tasks:

- Analyze the regional tectonics;
- Evaluate potential seismic source zones;
- Collect and plot instrumental seismic data from the NEIS and other applicable sources within a 200-mile radius around Cheyenne;
- Collect all up-to-date information on faulting in the study area;
- Based on the most recent data, select a deterministic or probabilistic method to evaluate seismic hazards;
- Review stress directions and stress provinces in the region;
- Review data on induced earthquakes near Denver and Rangely, Colorado, and make a preliminary evaluation of the potential for similar induced earthquakes in the DA; and
- Prepare a preliminary opinion on seismic risk (i.e., probabilities of exceeding a certain design acceleration within a specified time) based on accepted relationships (Algermissen and Perkins 1976, Algermissen et al. 1982, and Liu and De Capua 1975).

2.5.1.2 Faulting

A fault is considered a geologic hazard to the project if it is capable of generating an earthquake (i.e., an active fault) within a time period that represents a safety risk to the facility. The hazard from faulting can take two forms:

- Severe ground shaking; and
- Ground rupturing from primary displacements on the fault plane or from secondary effects on the ground surface due to the strong shaking (e.g., surface cracking, tilting, elevation changes, etc.).

Currently there are no universally accepted definitions for active and inactive faults (Slemmons and McKinney 1977). Definitions of active faults vary from those with very long recurrence intervals (500,000 years) to those with only historic surface displacement (about 200 years in the western United States). Faults may be dormant for hundreds and perhaps even thousands of years and then suddenly generate earthquakes; thus, most Quaternary faults have some potential for movement (Allen 1975).

For this study, faults with historic surface rupture or associated seismicity and faults with geologic and/or geomorphic evidence of Holocene (last 10,000 years) movement are considered active.

Three methods are commonly applied to faults to evaluate their capability to generate earthquakes and produce potential ground displacements. Faults are usually judged active if:

- Previous earthquakes have been or could reasonably be associated with a particular fault. The instrumental record can permit locating earthquakes with sufficient accuracy to make an association with a fault or other seismic source (arches, folds, intrusions, etc.).

- Movement on the fault, as reflected at the ground surface, has occurred within geologically recent time. As a result, the age of the last movement on the fault does not satisfy some minimum, pre-established age criteria. As explained in Section 2.5.1.1, Regional Seismicity, a fault is usually considered active if it demonstrates any tectonic movement within the last 10,000 years and could be considered active (according to conservative nuclear power plant siting criteria) if tectonic movements of a recurring nature have occurred within the last 500,000 years.

- Movement on a nearby fault could produce movement on the fault in question. If a particular fault shows no evidence of activity by the above methods, it may still be judged active if it has a structural connection with a known or suspected active fault.

2.5.2 Energy and Mineral Resources

The methodology employed to classify energy and mineral resources has been developed by the USBM in conjunction with the USGS and is a system accepted by regulatory and other agencies with decisionmaking responsibility. This classification relates issues of land use, assessments of potential environmental consequence, and surveys of global or regional resource potential.

Baseline data on energy and mineral resources include oil, gas, economic minerals, aggregate, etc. Based on previous Peacekeeper studies, information from the Intergovernmental Environmental Resource Workshops held in Cheyenne, specific site locations, and professional judgments, the only energy and mineral resource presently deemed an issue is aggregate because it will be affected by construction activities of the project. All remaining energy and mineral resources within the ROI will not be affected by the project for one or more of the following reasons: they are not known to exist within the ROI, or they exist in uneconomic quantities; they are already being produced and successfully coexist within the current DA configuration; or they are capable of being produced with little or no loss due to the project. Aggregate in the ROI is an abundant resource but identified as an impact because considerable quantities will be required for construction.

The steps in the evaluation of energy and mineral resources are:

- Review available literature and public records;

- Establish the geologic framework based on the review;

- Catalog occurrences of minerals known to exist but not present in sufficient quantity or quality for extraction;
- Inventory mineral occurrences known in the surrounding areas and assess the likelihood of their existence in the area of concern; and
- Consider the potential for occurrence of economic minerals not previously detected within the region through consideration of the geologic environment.

On this basis, identified resources are classified as measured, indicated, or inferred, and undiscovered resources are classified as hypothetical or speculative (Figure 2.5.2-1).

This information is then reviewed in terms of current and future economic trends, extraction technologies, and markets. On the basis of this review, the resources are then classified as economic, subeconomic, or marginal under the USBM/USGS classification system (USGS 1980).

2.5.3 Soil Resources

The soil properties described in the following subsections include agricultural properties, and potential wind and water erosion characteristics. Based on previous Peacekeeper studies, information from the Intergovernmental Environmental Resource Workshops held in Cheyenne, specific construction site locations, and professional judgment, soils will only be considered an issue in areas of new ground disturbance resulting from project-related construction.

Generalized soils analyses were conducted for areas A and B in the DA and along the 1-mile wide proposed cable route corridors. Area A consists of eastern Laramie County, Wyoming, and Area B is made up of southern Goshen County, Wyoming, and Scotts Bluff and Banner counties, Nebraska. This generic study required averaging many soil factors and extrapolating numerous equation parameters used in the analysis. More site-specific analyses (Section 3.5.3) were done along cable route PD1 for wind erosion, along cable route SC2 for water erosion, and at F.E. Warren AFB for both wind and water erosion. As a conservative measure, the soils with the highest erodibility indices were analyzed at these locations.

2.5.3.1 Agricultural Properties

Baseline soil conditions are based on soil use as a growth medium for food and fiber production. Soil classification within the study area is based on a system used by the SCS (1975a). This system defines soil at six levels of detail from the broadest definition at the order level to the most detailed at the series level.

Properties affecting the suitability of a soil as a plant growth medium include moisture, nutrient retention capability, depth, workability, and topography. Other phenomena (e.g., climate) have major influences on soil formation rates and the capability of a region to produce agricultural products.

CUMULATIVE PRODUCTION	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	DEMONSTRATED		INFERRED	PROBABILITY RANGE OR	
	MEASURED	INDICATED		HYPOTHETICAL	SPECULATIVE
ECONOMIC	RESERVES		INFERRED RESERVES		
MARGINALLY ECONOMIC	MARGINAL RESERVES		INFERRED MARGINAL RESERVES		
SUB-ECONOMIC	SUB-ECONOMIC RESERVES		INFERRED SUB-ECO. RESERVES		
OTHER OCCURRENCES	INCLUDES NON-CONVENTIONAL AND LOW-GRADE MATERIAL				

USGS-USBM CLASSIFICATION SYSTEM (USGS 1980)

CUMULATIVE PRODUCTION	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	DEMONSTRATED		INFERRED	PROBABILITY RANGE OR	
	MEASURED	INDICATED		HYPOTHETICAL	SPECULATIVE
ECONOMIC	1		3	4	5
MARGINALLY ECONOMIC	2		3		
SUB-ECONOMIC	3		3		

USGS-USBM RESOURCE CLASSIFICATION SYSTEM AS
MODIFIED FOR USE IN THIS STUDY

ENERGY AND MINERAL RESOURCE CLASSIFICATION SYSTEM

FIGURE NO. 2.5.2-1

A convenient scale for estimating the suitability of a soil to produce field crops is a land capability classification. The SCS (1975a) defines eight land capability classes, ranging from Class I soils which have slight limitations to Class VIII soils with limitations that nearly preclude their use for commercial crop production. The limitations can take any of several typical forms such as shallowness, droughtiness, climate, and erosiveness.

2.5.3.2 Potential Wind Erosion

Baseline conditions for wind erosion are analyzed by applying the Wind Erosion Equation to planned construction in the DA. Any estimate of wind erosion relies on the basic concept that transport is a function of wind shear velocity and soil particle size distribution. The equation was originally developed by W.S. Chepil and subsequently refined by Woodruff and Siddoway (1965). The present form of the equation is a complex equation indicating the relationship between potential soil loss from a field and 11 individual primary field and climatic variables.

The Wind Erosion Equation (SCS 1982a) states that E, the estimated soil loss in tons per acre per year (T/acre/yr), is a function of soil texture, soil ridge roughness, climate, length of unsheltered land, and vegetative cover. Appendix A elaborates on each of the variables in the Wind Erosion Equation and shows a sample calculation using the equation. It is possible to solve the equation in reverse to calculate any of the variables in the equation except the climatic variable. Application of the equation on a regional basis must be done cautiously, as several assumptions and extrapolations are necessary beyond those on which the Wind Erosion Equation was derived.

2.5.3.3 Potential Water Erosion

The baseline study of water erosion has been conducted on a generalized basis. One limitation of methods used for predicting potential water erosion for baseline conditions is the use of empirical algorithms for the calculation of unit soil loss. Although state-of-the-art techniques are based on current research data, it is necessary to make some extrapolations and approximations. Use of comprehensive and current data sets (including soil type distribution, chemical and physical properties of soils, and current land usage) provides the greatest reliability for the assessment.

Various methods have traditionally been available for estimating sheet and rill erosion in a watershed. Since the early 1970s, the Universal Soil Loss Equation (USLE), developed by the Agricultural Research Service in cooperation with the SCS, has become the dominant method used, and is followed here. This equation was originally developed for use only with cropland, haylands, and pastures in rotation, but various factors have been developed from research studies to extend its applicability to other situations.

The USLE makes quantitative predictions for construction-site sized plots (i.e., for slope lengths less than 400 feet and gradients between 3 and 18 percent). Quantitative predictions of the soil loss rate for a project requires the addition of soil losses from all the construction-site sized plots required to cover the project. Soil loss rates vary according to the size of a project. Often a few small areas contribute most of the soil loss. When extended to large areas, the USLE becomes at best a qualitative model of the erosion process. Also, the USLE does not take into account the deposition of soil eroded from other areas within the project.

The USLE is $A = R \cdot K \cdot L \cdot S \cdot C \cdot P$ where A is the computed soil loss from sheet and rill erosion in T/acre/yr, R is the energy intensity of rainfall, K the resistance of soil surface to erosion, L the length of the slope, S steepness of slope, C the crop management factor, and P the erosion control factor. Appendix A elaborates on each of the factors in the equation and presents a sample calculation of soil loss using the USLE.

Factors L, S, R, P, and C are investigated for the site-specific areas and a single average factor is deduced and applied for every assessment. Factor K is calculated more explicitly, by inspecting the distributions of soil map units and soil types within the site-specific areas.

Once values are computed for the five factors, the USLE is applied to describe the baseline conditions and the future baseline. Successive applications of the USLE are then used to provide comparative soil loss estimates to help guide decisionmaking concerning fluvial erosion effects and comparative benefits of alternative erosion control steps.

2.6 Existing Environmental Conditions

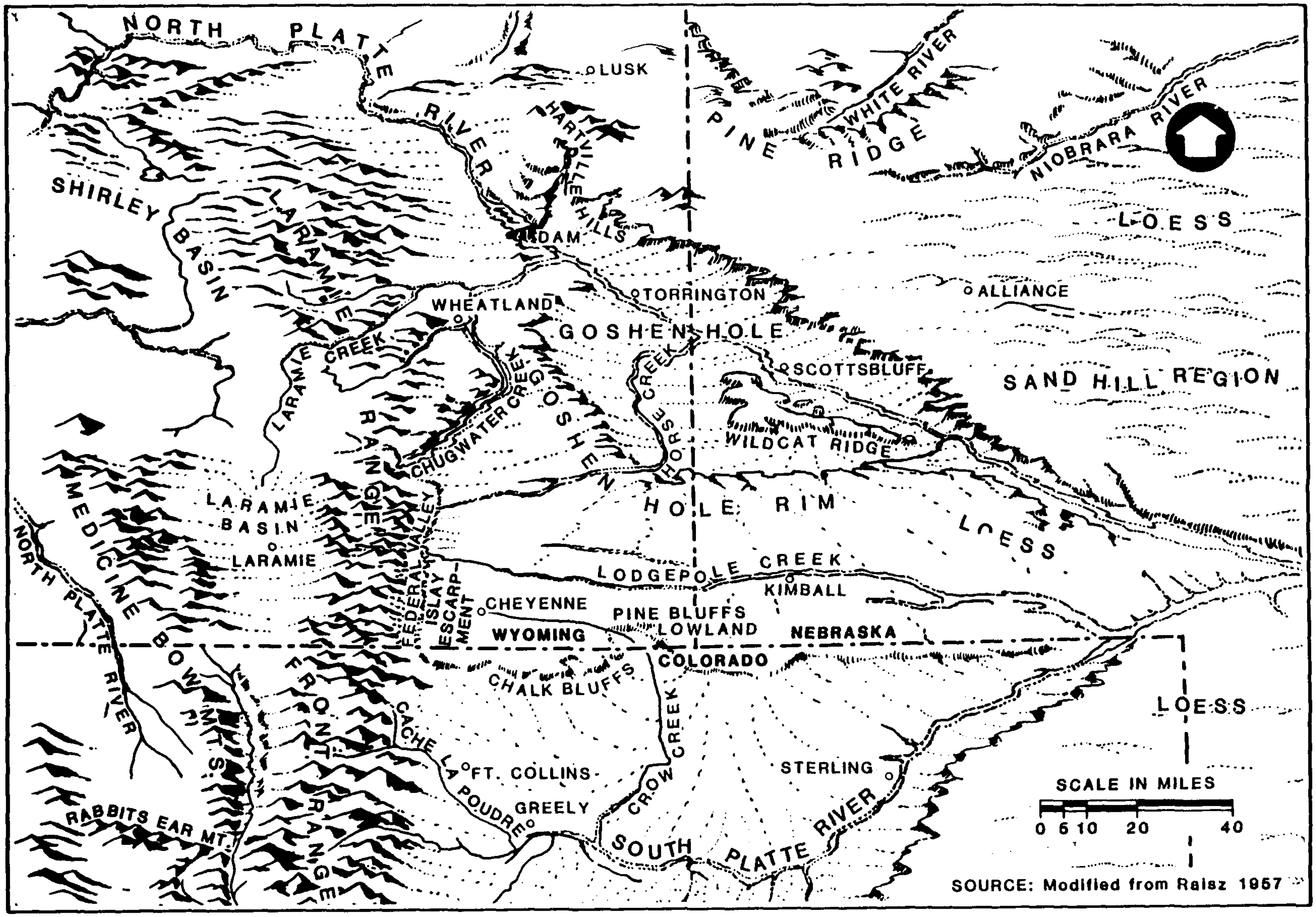
2.6.1 General

2.6.1.1 Physiography

The DA is located in the High Plains section of the Great Plains Physiographic Province. The High Plains surface is a gently rolling, east-sloping tableland with a slope of approximately 20 to 100 feet per mile (ft/mi). Elevations range from over 8,000 feet above sea level in the Laramie Range of south-central Wyoming to about 4,000 feet in northwestern Nebraska. In the DA, the Great Plains Physiographic Province is bordered on the west by the Laramie Range, part of the Southern Rocky Mountains Province.

The physiographic characteristics most significant to the geologic resources evaluation are the major drainages, hillsides, and badland areas. The major drainage channels and river valleys often are potential sources of aggregate. Slopes of the drainage channels and hillside areas are most capable of landsliding and the areas of badlands represent degrading landscapes susceptible to progressive erosion and soil loss.

The ROI is roughly bracketed on the north by the North Platte River and on the south by the South Platte River (Figure 2.6.1-1). Both rivers converge in western Nebraska. All other drainages within the DA are tributaries to these main rivers. The largest of these tributary drainages are Chugwater Creek and the Laramie River which flow north to northeast, Lodgepole Creek which flows eastward through the center of the DA, Crow Creek located south and west of Cheyenne, and Horse and Bear creeks which flow through the Goshen Hole Lowland. In Kimball and Banner counties, Nebraska, several drainage systems have been incised into the surface of the plain. Such drainages are Rocky Hollow, Lawrence Fork, and the broad valley of Pumpkin Creek where the valley bottoms approach 500 feet below the upland surface.



PHYSIOGRAPHY OF THE PROJECT AREA

FIGURE NO. 2.6.1-1

A major geomorphic feature in southern Platte and Goshen counties is the Goshen Hole Lowland, a wedge-shaped, erosional widening of the North Platte River Valley. The western edge of this lowland is marked by a pronounced east-facing escarpment with 500 to 600 feet of relief. Elevations within the lowland vary between 4,000 and 5,000 feet. Another prominent physiographic feature in the region is the Pine Bluffs Lowland about 30 miles east of Cheyenne which represents an alluviated lowland area.

Isolated areas of badland topography occur throughout the DA. One area is located east and west of Scottsbluff, Nebraska, along the upper reaches of the North Platte River. Another area is on the south side of Wildcat Ridge along Pumpkin Creek. A third area, on the eastern edge of the ROI, is developed near Sidney, Nebraska, along Lodgepole Creek, and a fourth area southwest of Sidney near Raymer, Colorado.

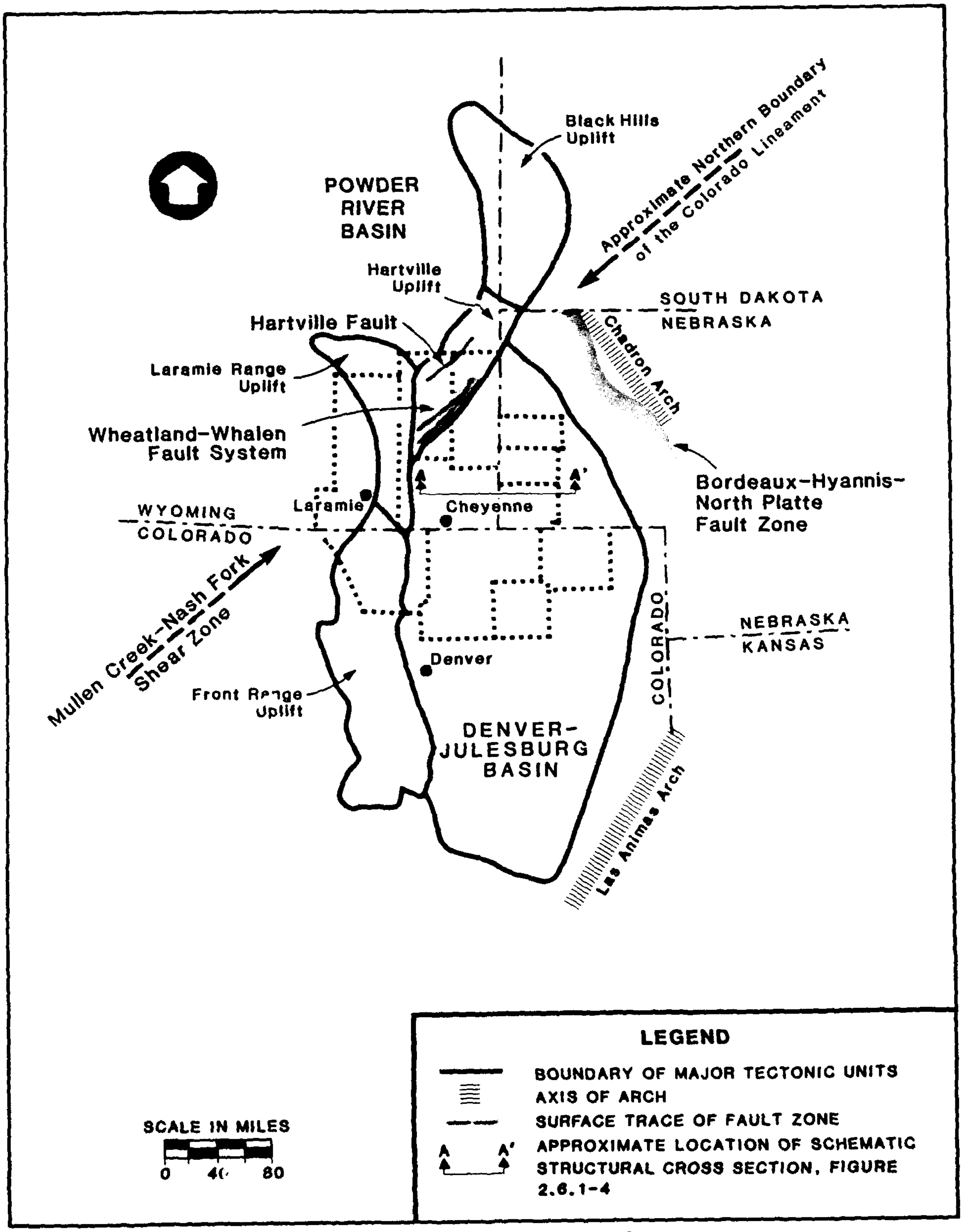
2.6.1.2 Stratigraphy

The DA lies within the northern portion of the Denver-Julesburg Basin and the southernmost portion of the Hartville Uplift (Figure 2.6.1-2). A generalized stratigraphic column for the northern Denver-Julesburg Basin is presented as Figure 2.6.1-3.

As much as 12,000 feet of sedimentary rock (Figure 2.6.1-4) underlies the Denver-Julesburg Basin. Paleozoic-age rocks consist of up to 1,300 feet of sandstone (Libra et al. 1981) and are exposed in a narrow belt along the front of the Laramie and Front ranges. The oldest known sedimentary rocks in the basin are coarse-grained conglomeratic sandstones of the Cambrian Flathead Formation. Triassic and Jurassic rocks in the Denver-Julesburg Basin consist of shales, siltstones, and sandstones with minor amounts of limestone, dolomite, and gypsum.

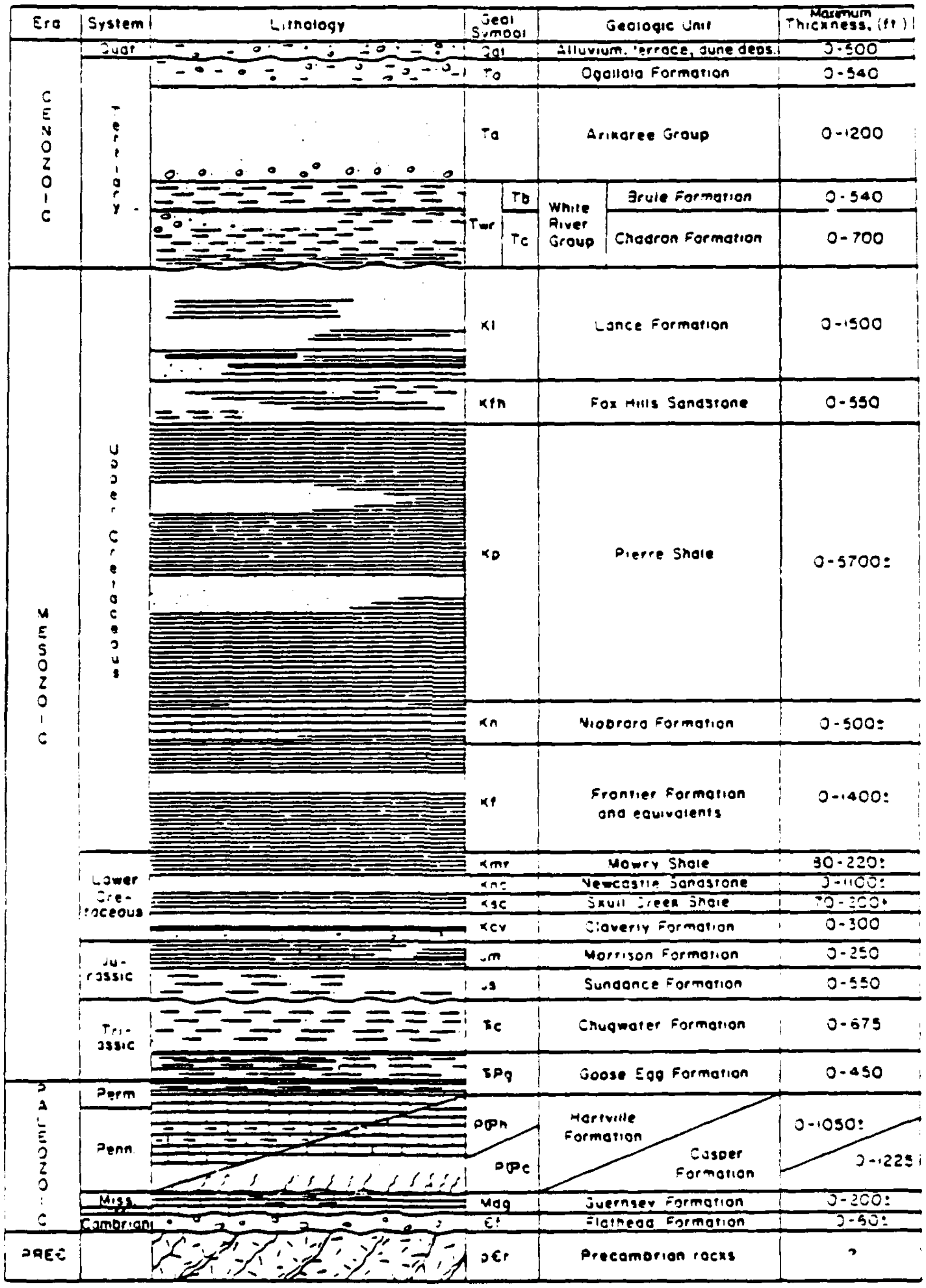
The Lower Cretaceous Dakota Group consists of a basal sandstone (Cloverly Formation/Fall River Sandstone) overlain by a shale (Skull Creek Shale) which in turn is overlain by another sandstone sequence (Newcastle Sandstone/Muddy Sandstone/"J" sand). The upper sandstone sequence of the Dakota Group is economically important as an oil and gas producer. Petroliferous horizons are primarily stratigraphic traps in the form of porosity wedge-outs in an easterly up-dip direction (McGinnis 1958). The majority of oil and gas production in Laramie County is from anticlinal traps. The Upper Cretaceous is represented by a sequence of marine shales (Frontier, Niobrara, and Pierre Shale formations) and an uppermost series of silty sandstones (Fox Hills Formation) and sandstone (Lance Formation).

The Tertiary stratigraphic sequence consists of the Oligocene White River Group, the Miocene Arikaree Group, and the Miocene/Pliocene Ogallala Formation. The White River Group is sometimes divided into the Chadron and Brule formations. The Chadron Formation consists of a lower fluviatile sequence ranging in grain size from clay to very coarse gravel, and an upper unit consisting mainly of bentonitic clay and silt with local occurrences of coarse-grained channel deposits, lenticular limestone beds, and volcanic ash. The Chadron Formation is up to 700 feet thick (Libra et al. 1981). The Brule Formation consists of bentonitic siltstone or silty claystone with local channel deposits of sand and sandstone, limey siltstone, and volcanic ash. In Goshen County the Brule Formation is up to 450 feet thick and is approximately 540 feet thick in Banner County, Nebraska (Smith and Souders 1975).



MAJOR STRUCTURAL FEATURES
OF THE DENVER-JULESBURG
BASIN REGION

FIGURE NO. 2.6.1-2

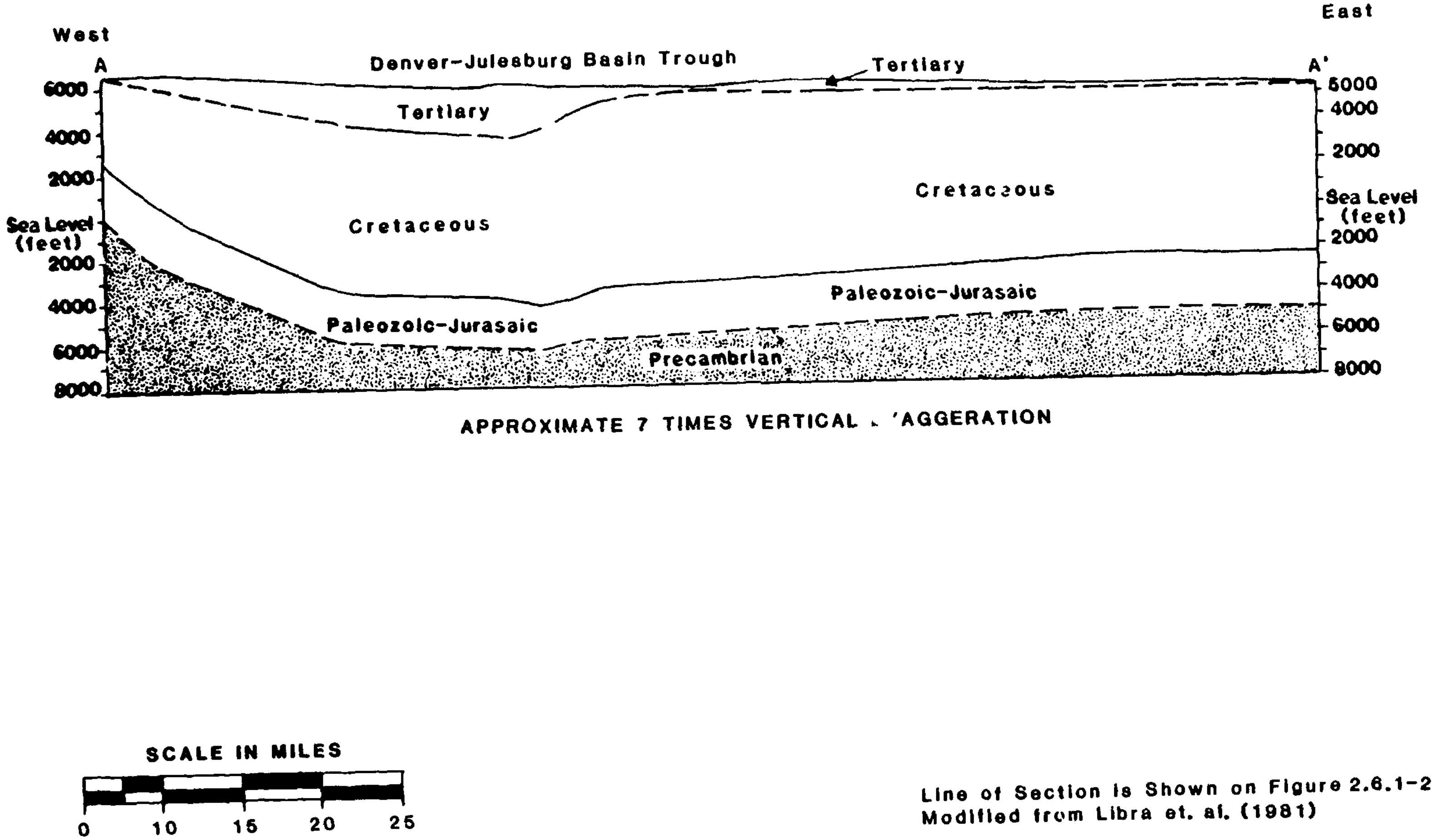


(Modified from Libra et al. 1981)

DATA SOURCES: Morris and Babcock(1960), Lowry and Crist(1967), Smith and Souders(1975), Gottula(1980), Libra et al.(1981)

GENERALIZED STRATIGRAPHIC COLUMN FOR THE NORTHERN DENVER-JULESBURG BASIN

FIGURE NO. 2.6.1-3



SCHEMATIC STRUCTURAL CROSS SECTION OF THE NORTHERN DENVER-JULESBURG BASIN IN THE VICINITY OF THE DEPLOYMENT AREA

FIGURE NO. 2.6.1-4

The Miocene Arikaree Group is a fine-grained massive sandstone which contains beds of siltstone and thin beds of volcanic ash. A basal conglomerate is present in many localities. The Arikaree is up to 1,200 feet thick in Goshen County (Libra et al. 1981) and thins to the south and east where it is about 400 feet thick in Scotts Bluff County (Darton 1903) and 500 feet thick in Laramie County (Cooley and Crist 1981).

The Miocene/Pliocene Ogallala Formation unconformably overlies the older rocks and contains beds of sand, gravel, silt, clay, and limestone. The Ogallala is over 300 feet thick in western Laramie County (Lowry and Crist 1967, USAFRCE-BMS 1983d) with a maximum of about 540 feet in Banner County, Nebraska (Smith and Souders 1975).

Quaternary deposits consist of alluvium, terrace deposits, and floodplain deposits which typically consist of lenticular beds of poorly sorted clay, silt, sand, gravel, and boulders. Alluvium along Lodgepole Creek is generally thin but may be up to 107 feet thick (Lowry and Crist 1967). Gottula (1980) reports 500 feet of alluvium near the confluence of Pumpkin Creek and Lawrence Fork Valley in western Morrill County, Nebraska. Alluvial deposits on the upland surfaces are generally less than 10 feet thick but may approach 90 feet thick in the major drainages such as the North Platte River.

Terraces are widely distributed in the DA and are generally topographically high. Most of the major drainages, the North and South Platte rivers, Laramie River, Lodgepole Creek, and Chugwater Creek, have terraces associated with them.

2.6.1.3 Structural Geology

The majority of the project area is located in the northern Denver-Julesburg Basin. The present structural configuration of the Denver-Julesburg Basin is the result of a long series of tectonic adjustments that have taken place continuously from Precambrian time to the present (McCoy 1953).

The Denver-Julesburg Basin is a large, asymmetrical, elongate basin underlying portions of eastern Colorado and smaller portions of western Nebraska and southeastern Wyoming (Figures 2.6.1-2 and 2.6.1-4). In the vicinity of the DA, the boundaries of the basin are formed by the Laramie Range on the west, the Hartville Uplift on the northwest, and the Chadron Arch on the northeast and east. The west flank of the basin is strongly folded and faulted adjacent to the Front and Laramie ranges. The eastern side of the basin has undergone only minor deformation (Murray 1957). The axis of the basin trends approximately north-south through Cheyenne. Near Cheyenne, the total relief between the Precambrian rocks of the Laramie Range and the trough of the Denver Basin is about 17,000 feet (Anderman and Ackman 1963). Approximately 7,000 feet of structural relief occurs between the Chadron Arch and the trough of the Denver-Julesburg Basin.

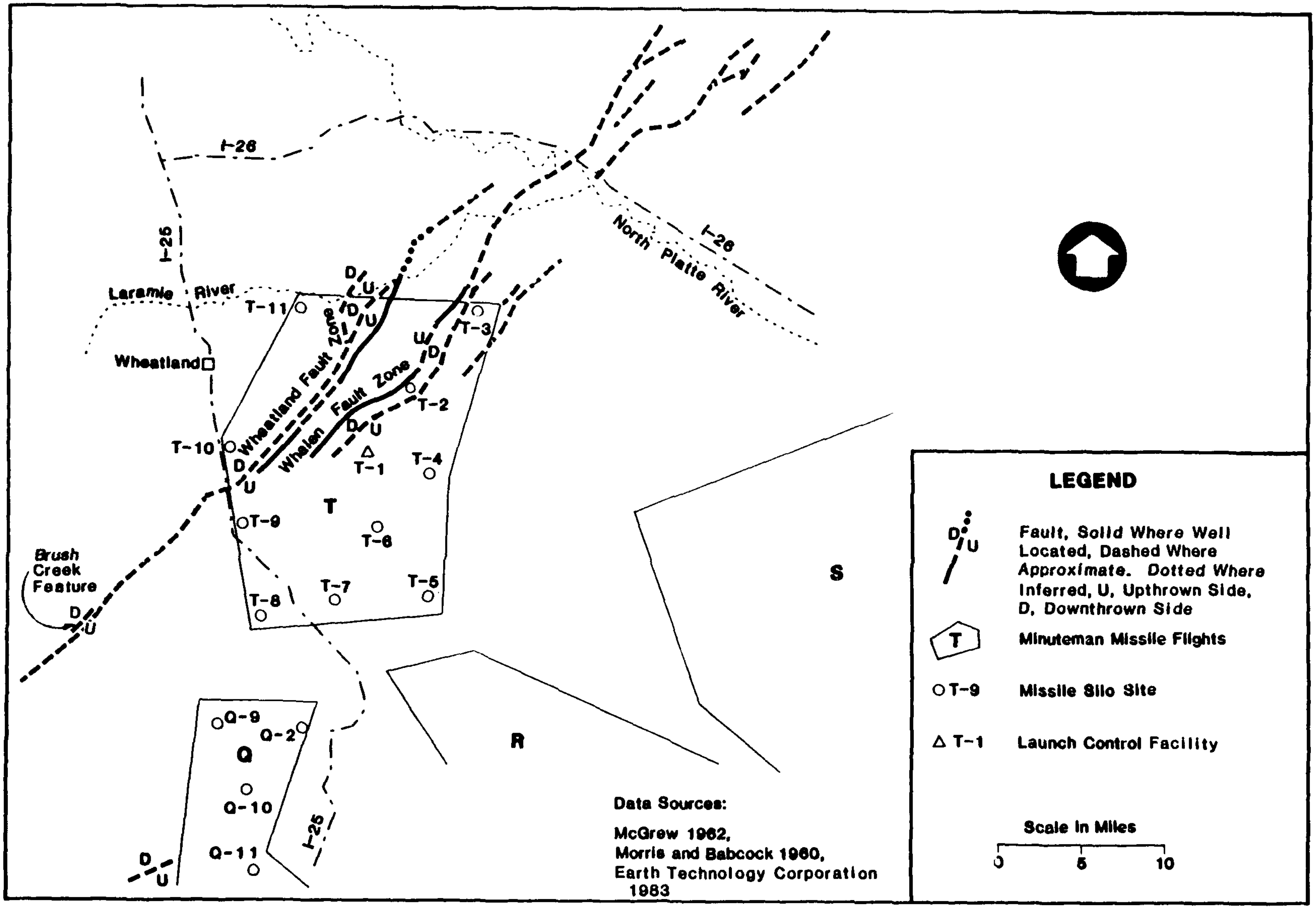
Tectonic deformation occurred intermittently throughout the Early to Middle Paleozoic in the vicinity of the DA. Maximum Paleozoic uplift occurred during Pennsylvanian time. The remainder of the Paleozoic and Mesozoic eras was characterized by relatively stable tectonic conditions and deposition of marine and nonmarine sediments. The Denver-Julesburg Basin, Hartville Uplift, and the Front and Laramie ranges essentially acquired their present structural configuration by the close of the Laramide Orogeny in Eocene time. Although the structural histories of the Laramie and the Front ranges are probably similar, it is thought by Anderman and Ackman (1963) that the magnitude of tectonic movement decreased northward.

The longest structural feature through the DA is the Colorado Lineament, a broad zone of faults postulated to extend from northwest Arizona to the Lake Superior region (Warner 1978). The lineament has been characterized as a zone of Precambrian shears about 100 miles wide which originated about 2,000 million to 1,700 million years ago (Penokean Orogeny). In the segment through southeast Wyoming and northwest Nebraska, the Colorado Lineament is defined on its northern boundary by the Mullen Creek-Nash Fork Shear Zone, a northeast trending zone of structural discontinuity passing though the northern Laramie Range and across the southeast limb of the Hartville Uplift (Figure 2.6.1-2). The Mullen Creek-Nash Fork Shear Zone separates basement rocks which are lithologically and structurally dissimilar, a characteristic of the Colorado Lineament at many locations along its length. Seismotectonic studies for Guernsey Dam (U.S. Bureau of Reclamation 1983) show the Mullen Creek-Nash Fork Shear Zone roughly aligns with the Wheatland Fault Zone in southeastern Wyoming (Figure 2.6.1-2).

The Hartville Uplift is a doubly plunging structural high which extends northeastward from the Laramie Range to the southwest flank of the Black Hills Uplift and separates the Denver-Julesburg Basin from the Powder River Basin on the northwest. The Wheatland-Whalen Fault System, located along the southeast flank of the Hartville Uplift, is described as a series of high angle faults with associated overturned beds and folds. The Wheatland-Whalen Fault System extends through the northwestern extreme of the ROI, across Flight T, and passes within less than a mile of two silos (Figure 2.6.1-5). The Wheatland Fault is downthrown to the northwest at the surface. The Whalen Fault exhibits up to 4,800 feet of displacement of Paleozoic strata and 300 to 700 feet of stratigraphic displacement in Tertiary beds. The most recently interpreted displacement associated with the Wheatland Fault Zone occurred 9,500 $\pm$ 400 years ago (McGrew 1962) which is sufficiently youthful to suggest the possible continuation of tectonic activity. This subject is further detailed in Section 2.6.2.2.

The Hartville Fault is a normal fault dipping about 70 degrees to the east and has a maximum displacement of 1,200 feet near the middle of its trace. The closest approach of this fault to the ROI is about 5 miles. An unnamed normal fault approximately 3 miles long is located immediately west of Flight Q (Lowry and Crist 1967, Figure 2.6.1-5).

The dominant structure of the western Nebraska area is the Chadron Arch which is the northernmost part of a number of linear, sinuous ridges that extend to the southeast from the Black Hills across Nebraska and much of Kansas (DeGraw 1969). According to DeGraw (1969), the arch is asymmetrical in cross section and appears to be normally faulted along its western and southwestern flanks. This fault zone is termed the Bordeaux-Hyannis-North Platte Fault Zone (DeGraw 1969). The strike of the fault zone varies between N20^{o}W to N40^{o}W. The vertical displacement along the Hyannis-North Platte segment ranges from 300 to 1,200 feet. The closest approach to the DA is about 60 miles.



LOCATION OF THE WHEATLAND-WHALEN FAULT SYSTEM IN RELATION TO FLIGHT T

FIGURE NO. 2.6.1-5

2.6.2 Geologic Hazards

This section discusses the existing conditions of the geologic hazards evaluated for the project and includes regional seismicity, faulting, subsidence, landsliding, and liquefaction. As previously stated, these evaluations have shown that the project will have no impact on geologic hazards. However, regional seismicity and faulting may have an effect on the project and are therefore addressed as a safety issue in the FEIS, Section 1.6.10.4.3.

2.6.2.1 Regional Seismicity

Seismic hazards are evaluated from historical seismicity, tectonic setting, and knowledge of geologically recent faulting. Seismic hazard for this report is based predominantly on historical seismicity.

2.6.2.1.1 Regional Seismic and Tectonic Setting

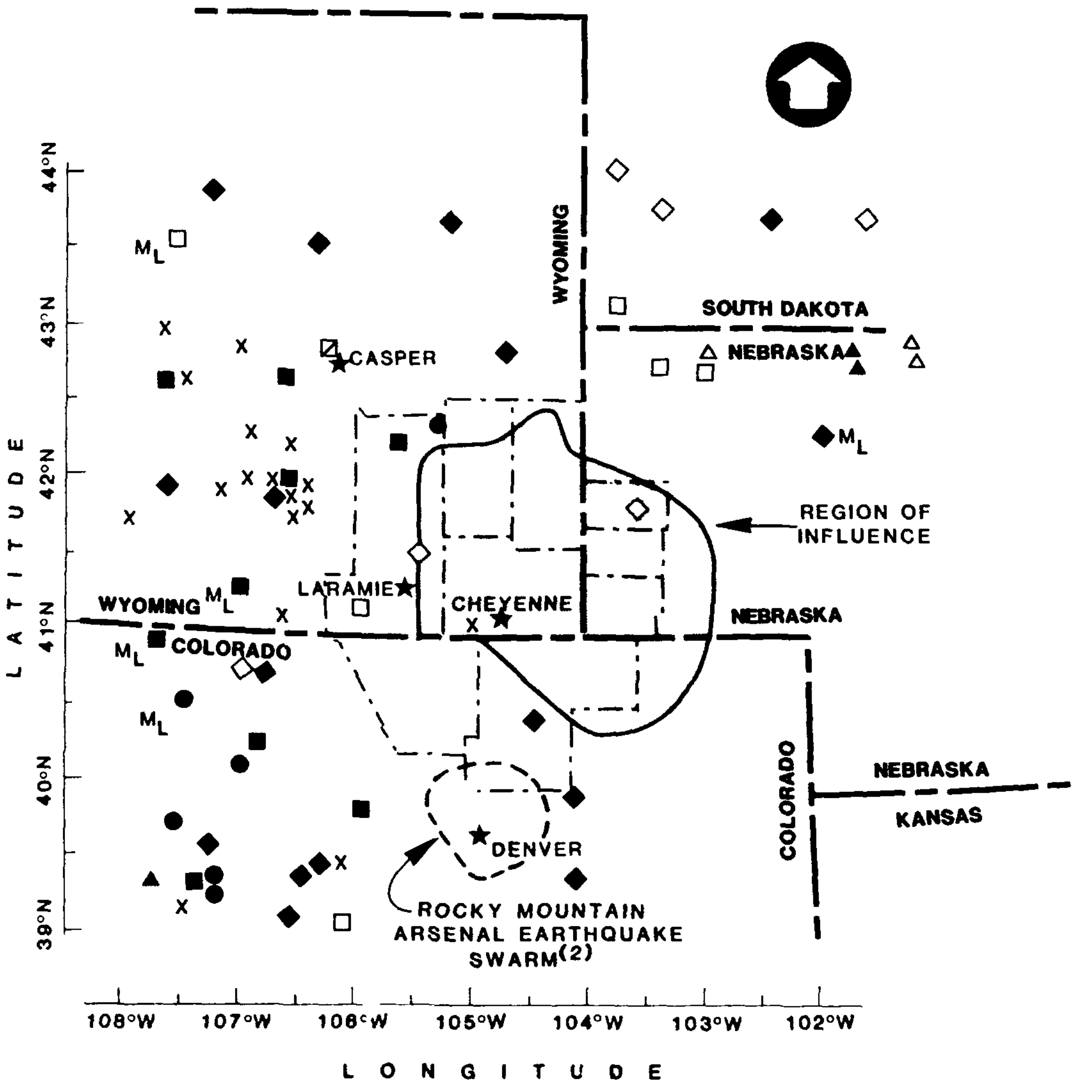
Figure 2.6.2-1 shows all reported earthquakes through August 1983 within about 200 miles of the DA, primarily based on data from the NEIS (Table 2.6.2-1). The DA has a relatively low level of seismic activity which is described in detail later in this section. Some of the earthquakes depicted in Figure 2.6.2-1 (e.g., those near Denver) have been induced by man's activities (Section 2.6.2.1.3).

As described in Section 2.6.1.3, Structural Geology, the DA is located at the northern end of the Denver-Julesburg Basin and is underlain by a thick, gently folded sedimentary section. The Wheatland-Whalen Fault System is about 40 miles west-northwest of F.E. Warren AFB. The Wheatland-Whalen Fault System is inferred to have moved during the Holocene because a small feature near the Wheatland Fault Zone is reported to have undergone Holocene displacement. Section 2.6.2.2 discusses the fault system in further detail. The Chadron Arch (Section 2.6.1.3) is reportedly faulted along its western and southwestern flanks by the Bordeaux-Hyannis-North Platte Fault trend. No seismic activity has been reported along this trend in the NEIS data; however, Nebraska researchers have interpreted several small earthquakes to be associated with the Chadron Arch.

An assessment of the regional seismic hazard was made based on the historical earthquake record and a comparison of the likely tectonic stress regime of the ROI with adjacent areas to the west. The DA is in the Mid-Continent Stress Province near the border of the Colorado Plateau Stress Province as defined by McGarr (1982, Figure 2.6.2-2). The generalized stress directions are at different azimuths in the two provinces. This transition zone between the two provinces is not marked by increased seismicity as are other parts of the Colorado Plateau perimeter which border tensional environments (e.g., the Northern Basin and Range, the Southern Basin and Range, and the Rio Grande Rift Stress provinces) and has no known tectonic characteristics which might be interpreted as possible seismogenic sources.

2.6.2.1.2 Historic Seismicity

Earthquake magnitude is expressed using three scales in this report. A local (Richter) instrumental magnitude (M_L) is a measure of the total energy released by an earthquake (within 100 kilometers of the epicenter), expressed



NOTES

1. Magnitudes are body wave magnitudes (m_b) unless otherwise noted.
2. For clarity, not all earthquakes around Denver are shown. Earthquake distribution associated with the Rocky Mountain Arsenal Swarm is as follows:

MAGNITUDE RANGE	NUMBER OF EARTHQUAKES
2.1 - 3.0	6
3.1 - 4.0	4
4.1 - 5.0	29
5.1 - 6.0	5

REFERENCES:

1. NEIS 1982, 1983.
2. Reagor et al. 1981.
3. Burchett, R.R. 1979.

Scale in Miles

0 40 80

LEGEND

Body Wave Magnitude		Modified Mercalli Intensity	
●	2.1-3	○	< III
■	3.1-4	□	III or IV
◆	4.1-5	◇	V
▲	5.1-6	△	VI
X	Unknown	▨	VII

EARTHQUAKES AROUND CHEYENNE, WYOMING THROUGH AUGUST 1983 (101° TO 108° W. LATITUDE AND 39° TO 44° N. LONGITUDE)

FIGURE NO. 2.6.2-1

Table 2.6.2-1

LIST OF EARTHQUAKE EPICENTERS WITHIN 200 MILES OF CHEYENNE, WYOMING

Earthquakes Around Cheyenne, Wyoming (104 75W, 41 25N) 39-44N, 101-108W

YEAR	M	D	HR	MN	SEC	LAT	LON	DEPTH	C	SOURCE	I	F	PHENOM	MB	MS	MO	AUT	ML	AUT	QU	AUT	DIST	NREP
1882	11	08	01	30	0 0	40 000	105 000			EQH	5	F									Z	141	1
1895	10	11	23	55	0 0	43 900	103 300			EQH	5	F									Z	318	1
1897	11	14	00	00	0 0	42 900	106 300			EQH	7	D									Z	224	1
1906	05	10	00	27	0 0	43 000	101 300			EQH	6	F									Z	345	1
1915	10	23	06	05	0 0	43 800	101 500			EQH	5	F									Z	389	1
1923	01	27	08	04	0 0	39 700	105 000			ISS												174	1
1924	01	04	21	56	30 0	39 700	105 000			ISS												174	1
1928	11	16	13	45	0 0	44 000	103 700			USE	5	F									Z	318	1
1944	09	09	04	12	18 0	39 000	107 500			CGS		F										342	1
1954	01	20	20	50	1 0	41 500	105 500			USE	5	F										68	1
1958	08	07	00	46	43 0	41 100	106 000			USE	4	F										106	1
1961	11	27	00	55	45 7	39 000	106 100	033	N	CGS	4	F										275	1
1962	12	04	17	49	59 4	39 800	104 700	033		CGS	6	D				350				012		161	1
1962	12	05	13	48	4	39 900	104 600	033		CGS		D				400	PAS			015		151	1
1963	01	30	23	05	9 6	39 800	104 600	033		CGS		F								005		162	1
1963	04	08	00	03	57 1	39 900	104 800	020		CGS										009		150	1
1963	04	24	22	29	34 4	39 800	104 700	020		CGS		F		410						009		161	1
1963	05	25	10	44	36 7	39 800	104 700	010		CGS	5	F								016		161	1
1963	06	05	00	13	50 6	39 300	104 000	033		CGS				440						005		226	1
1963	07	02	08	02	56 3	39 800	104 600	033		CGS	5	F		460						019		162	1
1964	03	28	09	08	45 0	42 900	101 600	041		USE	7	D		510								318	1
1964	03	28	10	08	45 0	42 900	101 600	041		CGS				510								318	1
1964	05	23	21	44	59 1	39 400	106 200	000		CGS			E								E	240	1
1964	08	04	11	13	25 2	39 700	106 000	033		CGS				400						008		202	1
1964	08	22	03	28	11 1	42 900	104 700	033		CGS	5	F		450						007		184	1
1964	08	26	16	58	51 6	43 800	102 200	015		CGS				440						005		352	1
1964	09	10	06	19	50 7	41 900	107 800	033		CGS				410						005		264	1
1965	02	16	20	17	53 5	39 900	105 100	005		CGS	4	F		460						006		153	1
1965	02	16	22	21	43 7	39 900	105 000	005		CGS	6	D		490						006		152	1
1965	05	30	17	31	4 1	39 400	106 300	033		CGS				430						008		244	1
1965	06	03	19	30	25 8	43 600	106 500	033		CGS				470						011		298	1

Table 2.6.2-1 Continued, Page 2 of 5
LIST OF EARTHQUAKE EPICENTERS WITHIN 200 MILES OF CHEYENNE, WYOMING

Earthquakes Around Cheyenne, Wyoming (104 75W, 41 25N) 39-44N, 101-108W

YEAR	M	D	HR	MN	SEC	LAT	LON	DEPTH	C	SOURCE	I	F	PHENOM	MB	MS	MO	AUT	ML	AUT	QU	AUT	DIST	NREP
1965	07	18	21	40	44 7	39 800	104 800	005		CGS	5	D		460						006		161	1
1965	07	31	13	41	42 8	39 700	104 900	005		CGS	5	F		460						005		173	1
1965	09	13	09	58	17 9	39 800	104 800	005		CGS	5	F		450						013		161	1
1965	09	14	16	36	46 8	39 800	104 800	005		CGS		F		470						006		161	1
1965	09	14	22	46	24 1	39 900	104 600	005		CGS	6	D		470						015		151	1
1965	09	14	23	16	10 4	39 500	104 900	005		CGS		F		480						005		195	1
1965	09	29	19	20	40 8	39 800	104 800	005		CGS	5	F		460						005		161	1
1965	09	29	23	22	58 0	39 800	104 800	005		CGS	4	F		460						005		161	1
1965	09	29	18	59	56 1	39 800	105 100	005		CGS	6	D		470						011		164	1
1965	11	21	03	59	58 9	39 800	104 800	005		CGS		F		460						006		161	1
1965	11	21	04	02	28 7	39 800	104 800	005		CGS	6	C		450						011		161	1
1965	11	21	04	24	48 5	39 900	104 700	005		CGS		F		440						005		150	1
1965	11	21	05	00	27 3	39 800	104 900	005		CGS		F		470						007		162	1
1966	01	02	00	13	41 8	39 900	104 800	005		CGS	3	F				210	GOL			005		150	1
1966	01	05	00	37	17 8	39 800	104 700	005		CGS	5	F		500						013		161	1
1966	04	03	16	21	34 0	39 363	106 462	000		CGS			E	470						016	E	255	1
1966	11	01	07	40	28 0	40 200	106 900	033		CGS				400						009		216	1
1966	11	14	20	02	35 9	39 900	104 700	005		CGS	6	D		410						011		150	1
1966	11	25	05	52	52 4	41 700	108 000	033		CGS										006		275	1
1966	12	19	20	52	33 3	39 000	106 500	005		CGS				460						005		291	1
1967	01	18	06	12	6	40 054	107 049	033	N	CGS				389						005	*	235	1
1967	02	03	05	27	58 3	39 872	104 794	011		CGS		F		400						008		157	1
1967	04	10	17	00	25 5	39 941	104 752	005	G	CGS	6	D		490						034		146	1
1967	04	10	19	36	38 0	39 890	104 768	005	G	CGS	3	F		440				350	GOL	006	*	151	1
1967	04	10	20	11	14 6	39 858	104 913	005	G	CGS	3	F		400						006	-	155	1
1967	04	10	23	58	40 8	39 923	104 791	005	G	CGS		F		400						010		148	1
1967	04	27	17	24	42 3	39 911	104 769	005	G	CGS	6	D		400				380	GOL	011		149	1
1967	05	11	21	15	6 6	48 663	105 899	033	N	CGS				400						009		284	1
1967	06	05	17	02	25 8	41 100	105 000	033		CGS										008		27	1
1967	06	19	15	39	22 0	39 900	104 800	005		USE	4	F				290				005		150	1
1967	08	09	13	25	6 2	39 900	104 700	005		USE	7	D		530						043		150	1

Table 2.6.2-1 Continued, Page 3 of 5
LIST OF EARTHQUAKE EPICENTERS WITHIN 200 MILES OF CHEYENNE, WYOMING

Earthquakes Around Cheyenne, Wyoming (104 75W, 41 25N) 39-44N, 101-108W

YEAR	M	D	HR	MN	SEC	LAT	LON	DEPTH	C	SOURCE	I	F	PHENOM	MB	MS	MO	AUT	ML	AUT	QU	AUT	DIST	NREP
1967	11	15	07	10	12 1	39 900	104 600	005		USE	5	D		370						011		151	1
1967	11	27	05	35	7	39 900	104 700	005		CGS				440						016		150	1
1967	11	27	05	42	53 3	39 900	104 900	005		CGS										005		151	1
1967	11	27	05	09	22 7	40 000	104 700	005		USE	6	D		520						041		139	1
1968	01	09	02	16	39 3	42 700	106 800	033		CGS				380						006		234	1
1968	06	23	20	16	13 0	39 314	107 409	033	N	CGS				380						008	*	312	1
1968	07	15	18	33	12 1	39 900	104 800	005	G	USE	5	D				340				007		150	1
1969	05	26	01	30	8 6	40 400	104 400	033	N	USE	4	F		420				350	GOL	005	*	99	1
1969	09	10	21	00	1	39 406	107 948	000		CGS			E	530						106	A	340	1
1970	05	23	08	55	9 4	39 900	105 100	005	G	USE	5	F		410				320	GOL	007		153	1
1970	12	12	15	57	19 1	43 958	107 545	015	G	NOS				490						016		378	1
1971	01	07	20	39	52 1	39 486	107 307	033	N	NOS		F		430				380	NOS	012		292	1
1971	03	18	09	08	59 9	40 705	106 970	010	G	NOS		F		440						014		196	1
1971	08	08	05	22	44 0	39 889	104 764	005	G	ERL		F		440				380	GOL	010	*	151	1
1973	04	13	21	17	52 6	41 852	106 680	010	G	ERL										011		174	1
1973	04	22	06	07	12 4	42 635	107 850	033	N	ERL		F		480						026		299	1
1973	05	29	21	34	13 1	42 366	107 104	033	N	ERL										008	*	231	1
1973	05	30	21	45	16 7	41 874	106 657	033	N	ERL										009	*	173	1
1973	06	01	21	22	21 3	41 879	106 708	005	G	ERL										007		177	1
1973	06	17	01	17	34 1	42 821	107 170	010	Q	ERL										006	*	265	1
1973	08	03	21	47	52 0	41 948	106 798	000	G	GS			E	410						013		187	1
1973	08	10	20	47	28 6	41 886	106 735	000	G	GS			E	360						008		180	1
1973	08	17	20	09	8 9	41 920	106 765	010	G	GS										008		183	1
1973	08	17	23	58	4 4	41 921	106 375	010	G	GS										006	*	154	1
1973	11	21	22	02	38 5	42 044	106 967	000	G	GS			E							008	*	204	1
1973	12	26	23	01	15 1	42 276	106 715	000	G	GS			E							009	*	199	1
1974	03	31	11	58	47 1	40 703	107 053	005	G	GS	2	F						350	GS	10		203	1
1975	05	16	05	57	1 5	43 238	103 681	005	G	GS	4	F								17	*	238	1
1975	07	11	16	39	22 1	41 977	106 731	005	G	GS										11	*	183	1
1975	12	19	23	26	19 5	42 849	107 649	000	G	GS								350	GRD	17	*	298	1
1975	12	30	23	12	48 0	42 981	107 864	005	G	GS										14	*	321	1

Table 2.6.2-1 Continued, Page 4 of 5
LIST OF EARTHQUAKE EPICENTERS WITHIN 200 MILES OF CHEYENNE, WYOMING

Earthquakes Around Cheyenne, Wyoming (104 75W, 41 25N) 39-44N, 101-108W

YEAR	M	D	HR	MN	SEC	LAT	LON	DEPTH	C	SOURCE	I	F	PHENOM	MB	MS	MO	AUT	ML	AUT	QU	AUT	DIST	NREP
1976	01	27	10	54	38 7	41 946	107 218	005	G	GS		F								14		219	1
1977	03	03	17	50	28 0	41 242	107 147	005	G	GS		F		42				350	GS	16		200	1
1977	09	24	11	16	48 4	39 309	107 311	005	G	GS		F		40				300	GS	23		306	1
1978	01	16	03	50	1 7	42 435	105 322	005	G	GS		F						300	GS	8	*	140	1
1978	05	07	16	06	19 6	42 303	101 928	015	G	GS	5	F				400	SLM	430	GS	15	*	262	1
1978	05	29	16	45	18 0	39 275	107 322	005	G	GS								300	GS	17		310	1
1978	06	06	21	23	34 7	43 632	107 826	005	G	GS				40				370	GS	15	*	366	1
1978	06	10	20	57	53 5	39 785	104 871	020	G	GS	4	F						290	GS	6	*	163	1
1978	11	30	18	50	15 8	40 471	107 607	005	G	GS								280	GS	6	*	255	1
1979	01	20	6	59	8 4	40 818	107 861	5	G	GS								330	GS	11	*	265	1
1981	03	24	13	03	40 0	39 751	104 936	005	G	GS		F						280	GS	5	*	167	1
1981	04	02	16	10	6 4	39 910	104 964	008	G	GS	6	D		43		450	TUL	300	GS	41	Q	150	1

YEAR	M	D	TIME UTC	LAT	LON	MAG
1981	09	16	19-58-40	39 835	105 005	2.1
1981	11	02	03-03-00	39 519	105 298	2.8
1982	03	11	23-55-29	39 860	104 853	2.8
1982	08	31	22-02-18	42 776	108 814	3.2
1982	09	18	16-11-45	39 902	104 912	2.8
1982	11	22	10-09-01	39 739	107 581	2.9
1983	02	13	13-44-44	42 238	105 726	4.0

Table 2.6.2-1 Continued, Page 5 of 5
LIST OF EARTHQUAKE EPICENTERS WITHIN 200 MILES OF CHEYENNE, WYOMING

YEAR	M	D	CENTRAL STANDARD TIME	LAT	LON	MODIFIED MERCALLI (MM) INTENSITY
1906	06	09	18:27	43 000	101 300	VI
1933	08	08	-----	41 867	103 667	IV-V
1934	07	30	01:20	42 850	103 000	VI
1938	03	24	07:11	42 683	103 417	IV
1963	03	09	09:25	42 850	103 000	II-III

(Source: A. DOCEKAL, 1970)

EXPLANATION

I Maximum Modified Mercalli Intensity (5-V, 6-VI, etc).

F Cultural effects (C = Casualties, D = Damage, F = Felt, H = Heard) An F in this column with no intensity in previous column is likely associated with an intensity of I-III on the Modified Mercalli Scale.

PHENOM Associated Phenomena.

DIST Distance from site to the epicenter in miles/kilometers.

NREP Repetitions. A 1 indicates that there is a single record in the list for this earthquake.

MB Body wave magnitude m_b (two decimal places, i.e. 430 = 4.30.

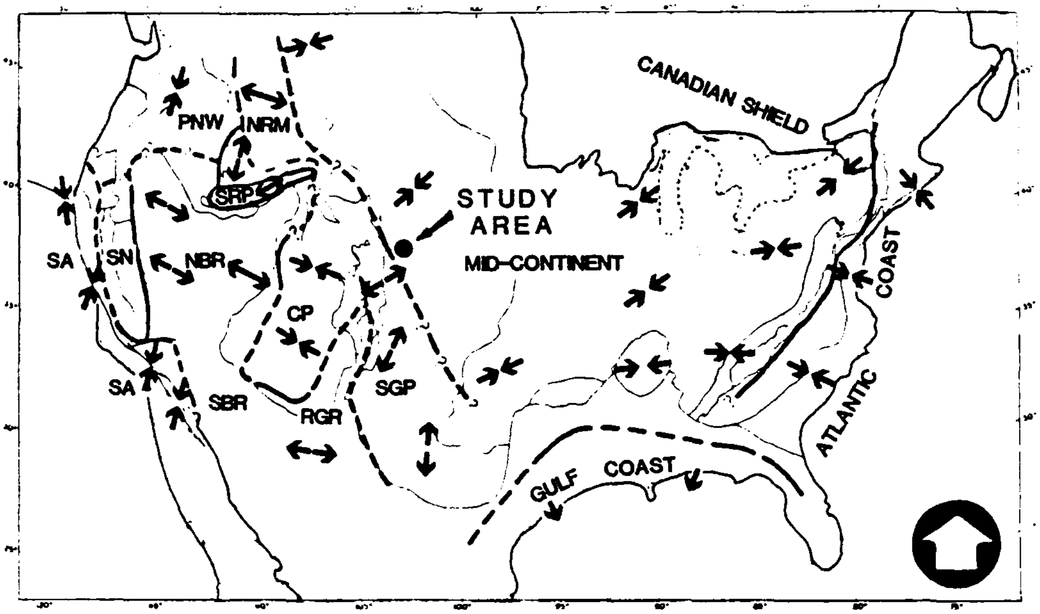
MS Surface wave magnitude M_s (two decimal places).

MO, AUT Other magnitude and source of the data. Value obtained from various sources: unspecified magnitude type but generally M_s (two decimal places).

ML, AUT Local magnitude ML and source of the data (two decimal places).

QU Number of stations/quality. Number of P and/or P' arrivals used in hypercenter solution.

AUT Authority for time and coordinates of other quality indicators. Blank indicates that the authority is the same as given under SOURCE.



FROM McGARR,1982 (AFTER ZOBACK AND ZOBACK,1980)

LEGEND

⇐⇒ PRINCIPAL STRESS DIRECTIONS

— - - BOUNDARIES OF STRESS PROVINCES: DASHED WHERE APPROXIMATE

SA	San Andreas
SN	Sierra Nevada
PNW	Pacific Northwest
NRM	Northern Rocky Mountains
NBR	Northern Basin and Range
SBR	Southern Basin and Range
CP	Colorado Plateau
RGR	Rio Grande Rift
SGP	Southern Great Plains
SRP	Snake River Plain

PRINCIPAL STRESS DIRECTIONS AND STRESS PROVINCES IN THE CONTIGUOUS UNITED STATES

FIGURE NO. 2.6.2-2

on an open-ended, logarithmic scale. The largest known magnitudes worldwide are about 8.9. The M_L scale is most often used in conjunction with damage or design accelerations. A body wave magnitude (m_b) is determined at large distances from the epicenter using the logarithm of the ratio of amplitude to period of the body waves. There is no universally accepted way to convert magnitudes from one scale to another. However, for the events reported for the vicinity of the ROI, M_L values averaged about 0.7 units lower than m_b values. Modified Mercalli Intensity (MMI) is a numerical index describing the effects of an earthquake on the earth's surface, on man, and on structures (Table 2.6.2-2). The MMI values range from I (not felt or only rarely felt) to XII (total destruction). An MMI of V represents very slight damage to conventional structures which are not designed or constructed to resist earthquakes. A combination of instrumentally recorded data and MMI data have been used to give the most complete representation of historic seismicity in the DA.

Few natural earthquakes (i.e., not induced) above the micro-earthquake level (magnitude M = 3) have been reported in the vicinity of the DA (Figure 2.6.2-1). NEIS data show only three earthquakes within the ROI (Figure 2.6.2-1). The largest magnitude earthquake (MMI = V) within the ROI occurred about 50 miles northwest of Cheyenne in Albany County near the western boundary of the ROI. A second event of magnitude MMI = IV to V occurred in Scotts Bluff County. The third event (of unknown magnitude) occurred about 17 miles southwest of Cheyenne. The largest earthquakes within about a 180 mile radius of the ROI have magnitudes of m_b = 5.1 to 6. Five events in the 5.1 to 6 (m_b) range are associated with the Rocky Mountain Arsenal Earthquake Swarm (Section 2.6.2.1.3). Two additional events with m_b = 5.1 to 6 have been reported about 250 miles northeast of Cheyenne near the South Dakota-Nebraska state line. Additionally, a MMI = VII event occurred near Casper, Wyoming.

Small instrumentally recorded earthquakes (M_L = 3 or less) are typically not listed by the NEIS. Such shocks may be felt at the epicenter but would be well below the damage-causing threshold. Not all seismicity has been reported in the NEIS; small earthquakes in the range of Intensity III to VI have been reported in western Nebraska (Reagor et al. 1981, Figure 2.6.2-1) near the Chadron Arch. Although the numbers are sparse and magnitudes of these events are typically low, a general southeast trend of several events has led some researchers to speculate an association with the Chadron Arch.

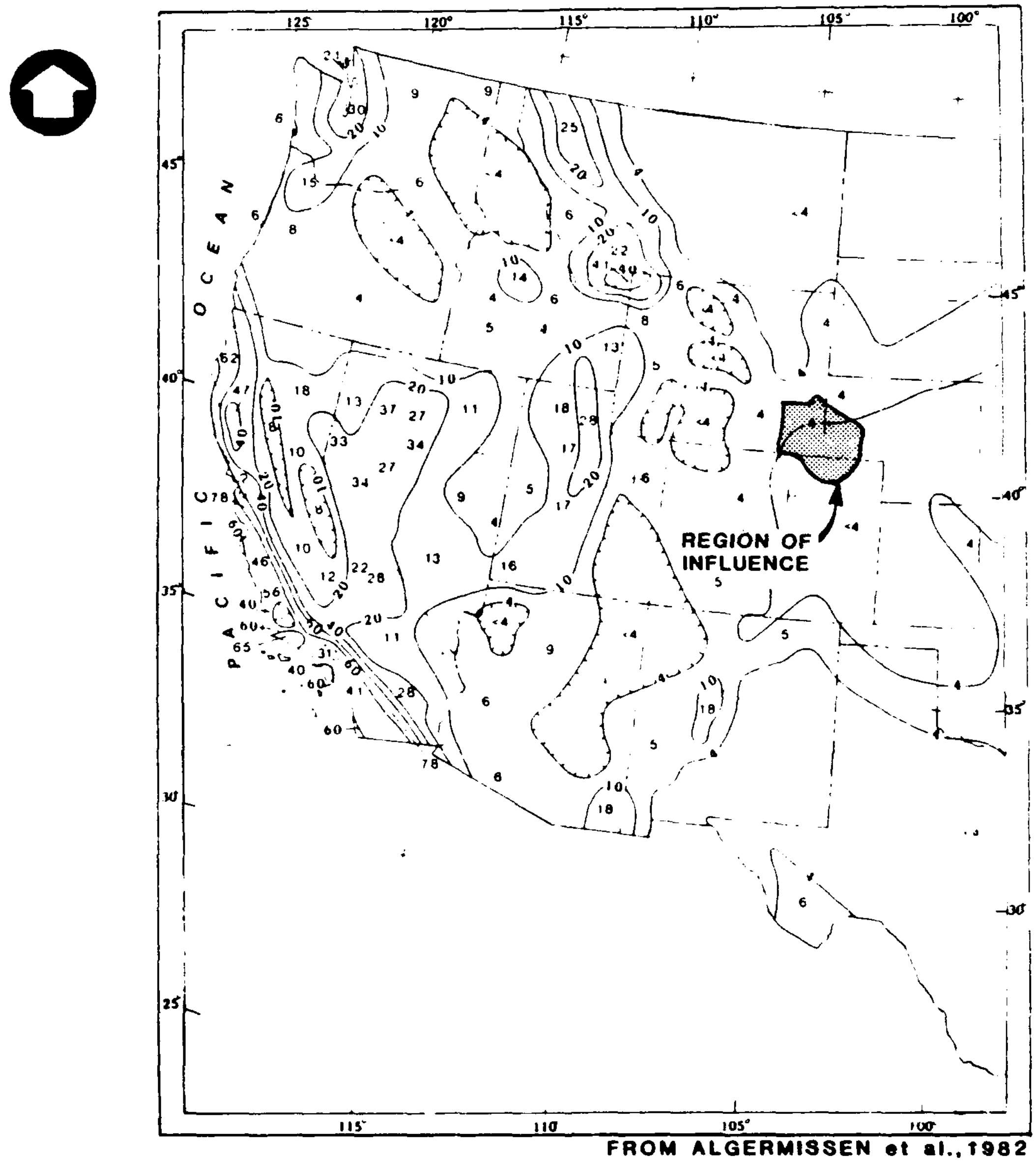
Based on the historical record, seismic activity in the vicinity of the DA is very low and would not be of great concern in the design of structures in the region. Algermissen and Perkins (1976) and Algermissen et al. (1982) indicate that the 475-year return period (10% chance of exceeding in 50 years) design acceleration would be about 0.04g for the Cheyenne area (Figure 2.6.2-3). A similar study for the Rocky Mountain states by Liu and De Capua (1975) indicates a design value of about 0.02g for a 200-year period. These studies are based on historical seismicity distributed over interpretive seismic source zones usually corresponding to physiographic or seismotectonic provinces. Because of the relatively low seismicity of such provinces encompassing or adjacent to the DA (e.g., the Colorado Plateau, Great Plains, and Mid-Continent), variations in seismic source zones in the area interpreted by future investigators are not likely to substantially increase the published estimates. Seismic risk in the area would be primarily attributed to a modest

Table 2.6.2-2

MODIFIED MERCALLI INTENSITY SCALE

Intensity	Effect
I	Not felt except by a very few under especially favorable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: Modified from Burchett 1979.



PRELIMINARY MAP OF HORIZONTAL ACCELERATION
(EXPRESSED AS PERCENT OF GRAVITY) IN ROCK WITH
90 PERCENT PROBABILITY OF NOT BEING EXCEEDED IN 50 YEARS

SCALE IN MILES

0 150 300 450 600

ACCELERATION CONTOURS

FIGURE NO. 2.6.2-3

earthquake (M_L = 5.0-5.5) which is assumed capable of occurring randomly throughout the region at the average depth of observed historical earthquakes. Earthquakes at this level are only sometimes damaging to conventional structures and have a relatively short duration, e.g., on the order of 5 to 8 seconds for rock (Krinitzky and Chang 1977).

2.6.2.1.3 Induced Earthquakes

There are two reported instances of man-induced earthquakes in the vicinity of the DA. Simon (1972) suggests that the filling of Lake Hattie Reservoir may have triggered a M_L = 3.5 event about 62 miles west of Cheyenne. Two earthquakes near Casper, Wyoming (Figure 2.6.2-1), may be related to oilfield water flooding. Correlations between earthquakes and oilfield pressurization have been shown by experiments (Raleigh et al. 1976).

Just south of the ROI, near Denver, Colorado, there is a concentration of earthquakes typically called the Rocky Mountain Arsenal Earthquake Swarm. These shocks reached magnitudes of m_b = 5.3. For the purposes of assigning damage potential, the largest Denver earthquakes are about M_L = 4.6. This concentration of earthquakes near Denver is generally acknowledged to have been triggered by high pressure wastewater injection at depths of several thousand feet (Evans 1966). Wastewater injection is now controlled, so the accelerated occurrence of earthquakes observed in the Denver area would not be anticipated in the future. Such earthquake swarms are not expected elsewhere in the DA.

The earthquakes near Casper and Denver are sufficiently distant from the DA, so that should activity continue at past levels or at any reasonably anticipated higher level, there should be no effect on surface structures.

2.6.2.2 Faulting

The two most likely areas near or within the ROI which have the potential of producing earthquakes are: the Bordeaux-Hyannis-North Platte Fault Zone east of the ROI in Nebraska and the Wheatland-Whalen Fault System in the northwestern portion of the ROI (Figure 2.6.1-3).

The Bordeaux-Hyannis-North Platte Fault Zone trends about N40W and extends for approximately 150 miles along the west-southwest limb of the Chadron Arch. The fault zone was inferred along the steeper west edge of the asymmetrical arch because of a pronounced change in depth of the underlying Cretaceous formations. Interpretations of dip slip displacement on this normal fault range from 300 to 1,200 feet. The age of last displacement is not known; however, there are no known reports of surface rupture or anomalies suggestive of recent faulting. Some researchers in Nebraska have recognized a diffuse pattern of small earthquakes extending northwest across the vicinity of the Chadron Arch. This has led to the suggestion that the earthquakes are associated with the Chadron Arch and, more specifically, the Bordeaux-Hyannis-North Platte Fault Zone (University of Nebraska 1983).

The Bordeaux-Hyannis-North Platte Fault Zone lies about 60 miles east of the ROI at its closest approach. A few small earthquakes have been interpreted to possibly be associated with this fault zone (DeGraw 1969). This association suggests that the fault zone may be classified as active based on the previously stated criteria (Section 2.5.1.2). However, the distance from the Bordeaux-Hyannis-North Platte Fault Zone to the DA is basically sufficient to preclude this fault zone from causing a seismic risk to the project. This conclusion is primarily based on the following: 1) there is no danger of surface rupture from this fault in the DA, and 2) the ground shaking associated with an earthquake on the Bordeaux-Hyannis-North Platte Fault Zone, regardless of magnitude, would be sufficiently attenuated by the time it reaches the DA to pose no threat to the components of the missile system.

The Wheatland-Whalen Fault System is actually two parallel fault zones along the southeast flank of the Hartville Uplift. Both the Wheatland and Whalen zones roughly parallel the crests of anticlines: the Wheatland Fault parallels the Wheatland Anticline and the southern portion of the Whalen Fault parallels the Greyrocks Anticline. Both faults trend northeast and range from 1 to 4 miles apart. North of the ROI, published maps indicate the two fault zones may converge. The Wheatland and Whalen Fault zones are 35 and 40 miles long, respectively. Together the overall length of both zones is about 55 miles.

Major structural characteristics of the Wheatland and Whalen Fault zones are somewhat similar. Both zones consist of high angle normal faults with displacements ranging from 900 feet (post-Miocene-Pliocene) for the Wheatland Fault to about 300 to 1,200 feet (post-Mid-Miocene) for the Whalen Fault.

Most of the displacement along the Wheatland-Whalen Fault System is interpreted to have occurred in latest Miocene and Pliocene time (McGrew 1962), but some displacement may have continued into Quaternary time. A small feature of possible fault origin, the Brush Creek feature, is located adjacent to the Wheatland Fault and is reported to have offset strata dated from 9,500 $\pm$ 400 years to about 1,520 years (McGrew 1983). These data suggest that the Brush Creek feature, and, by association, the Wheatland-Whalen Fault System, is an active fault based on the definition of active fault being used in this report. However, other evidence suggests the Wheatland-Whalen Fault System is not active. This evidence includes: 1) the present morphological expression of the Wheatland and Whalen Fault scarps, 2) the possibility that the dated feature at Brush Creek may be a localized landslide or other nontectonic feature, and 3) the overall degree of reported observations on the Brush Creek feature (e.g., 10-foot wide gouge zone and about 20 feet of displacement) which are indicative of a major surface rupture, not a geographically small feature as identified at Brush Creek. These data are further elaborated by the Earth Technology Corporation (1983). Although there is data to suggest the Wheatland-Whalen Fault System is not active, these data are inconclusive and therefore, for the purpose of this study, the fault system is conservatively being considered active.

Reanalysis of the Wheatland-Whalen Fault System by the U.S. Bureau of Reclamation (1983) basically discounted the evidence presented by McGrew (1962) and concluded the Wheatland Fault not to be active. However, the study by the Bureau of Reclamation was based on available literature and an aerial photograph analysis and did not produce any field evidence to disprove the field data generated by McGrew (1962).

The trace of the Wheatland-Whalen Fault System trends northeast through Flight T (Figure 2.6.1-5). Launch Facilities T-2 and T-3 lie within the fault system and T-9 lies along its projection to the southwest. If tectonic movement occurs on the fault system, there will be potential for ground rupture in the area.

Preliminary estimates for a maximum credible earthquake on the Wheatland-Whalen Fault System could range up to a magnitude 7.5 depending on the relationships utilized (Earth Technology Corporation 1983). Assuming the Wheatland-Whalen Fault System is active, the seismic potential of the northwestern portion of the DA would be greater than for the entire region.

2.6.2.3 Subsidence

For subsidence to occur, there must be some form of volume decrease beneath the earth's surface. The decrease in volume may arise from several phenomena: solution thawing in permafrost areas, compaction, slow crustal warping, excessive fluid withdrawal (oil/groundwater) or mining activities. No documented occurrences of subsidence are known to have occurred within the DA. Further discussion of the potential for project-induced subsidence from groundwater withdrawal is presented in the Water Resources Environmental Planning Technical Report (EPTR), Section 3.5.4.

2.6.2.4 Landsliding

Landsliding is a mass movement process involving downslope transport of soil and rock materials under gravitational forces. The overall slope of the DA is relatively gentle including the preliminary locations of the proposed cable routes. Only one very small documented landslide located along the T21N/T22N line in R69W in southwest Platte County is known to have occurred in the project area (Figure 2.6.2-2). Therefore, landsliding is not considered a major issue. Local failures may occur along some of the steeper slopes in the major channels and badland topography developed in western Nebraska.

2.6.2.5 Liquefaction

Liquefaction is a process by which soil is transformed from a solid to a liquid state as a result of increased pore fluid pressures and a reduction in the effective stress. The conditions required to produce liquefaction in a soil include low relative density, shallow depth (not greater than 50 to 100 feet), complete saturation, and strong shaking with sufficient duration to produce cyclic loading. The existing Minuteman silos and the proposed locations of the new cable routes are not located in an environment that meets these conditions. Therefore, liquefaction is not considered an issue.

2.6.3 Energy and Mineral Resources

Energy and mineral resources of current and potential economic value in the northern Denver Basin include: 1) uranium in the subsurface basin interior; 2) limestone, gypsum, sandstone, and granite along the eastern margin of the Laramie Range; 3) hydrocarbons including oil, gas, and coal in the subsurface basin interior; and 4) surficial sand and gravel deposits (Figures 2.6.3-1 and 2.6.3-2).

With the exception of the surficial sand and gravel deposits (aggregate), all of the previously mentioned resources are not affected by the project for one or both of the following reasons:

- The resource is not known to exist within the DA or if it does exist, it is in uneconomic quantities or of a hypothetical or speculative nature (USGS 1980).

- The resource is already in production and is currently coexisting with the present deployment configuration, and implementation of the project will have little if any effect on future production of the resource.

2.6.3.1 Aggregate Resources

Aggregate materials (Figure 2.6.3-1) occur in a variety of environments throughout the ROI including:

- Sand and gravel associated with stream channels and terraces;

- Sand and gravel in outcrops of the Ogallala Formation;

- Sand and gravel in outcrops of other poorly consolidated sedimentary units, typically along the Laramie Range; and

- Crystalline rocks suitable for crushing which include granite and metamorphic rocks found in the core of the Laramie Range, and the upturned limestone and dolomite beds flanking the core.

It is possible that many upland areas between drainages are composed of aggregate suitable for project use. However, based on the available data, it is not possible to predict their distribution with any accuracy. Figure 2.6.3-1 does not show upland sand and gravel deposits as an aggregate source.

Aggregate must meet established standards of abrasion resistance, chemical compatibility, and soundness to be suitable for use in concrete. The requisite characteristics for use of aggregates in road beds are less rigorous, but resistance to abrasion is nevertheless important.

Current aggregate production in the ROI is largely on an as-needed basis and comes from several sand and gravel pit operations and limestone/dolomite/granite quarries. Limestone and granite quarrying operations near Granite, Wyoming, as well as limestone/dolomite production near Horse Creek and Guernsey, Wyoming, and Laporte, Colorado, are major sources of crushed rock aggregate in the region.

Preliminary project sand and gravel requirements are estimated at 4.6 million tons or approximately 2.6 million cy. Major sand and gravel producers in or near the ROI report reserves of about 160 million tons (Table 2.6.3-1; personal communication 1983). Crushed rock producers report approximately 212 million tons of granite, limestone, and dolomite reserves.

These tonnages should not be construed as the total amount of aggregate/crushed rock within or adjacent to the ROI. The estimated reserves presented in Table 2.6.3-1 reflect only the acreage currently owned or leased by the 18 major aggregate/crushed rock producers. Additional suitable acreage exists within the ROI but is not controlled by the producers and therefore is not readily available for extraction. Additionally, only major aggregate producers were surveyed. Many small pits and quarries in the ROI serve only very local areas and do not have the extensive acreage typical of the major producers.

Table 2.6.3-1

AGGREGATE RESERVES IN AND ADJACENT TO THE REGION OF INFLUENCE

Sand & Gravel	Number of Producers Surveyed	Total Acreage	Estimated Reserves[1] Million Tons
Platte, Goshen, Laramie counties	6	950	44.4
Scotts Bluff, Kimball, Banner counties	5	195	8.5
Weld, Logan, Morgan counties	3	2,300+	109.2
TOTAL:	14		162.1
Crushed Stone			
Entire ROI	4	N/A	212.0

Notes: 1 Based on 43,560 tons of aggregate per acre (10-foot thick deposit) or producers own records.

2.6.3.2 Other Construction Materials

2.6.3.2.1 Cement

The production of cement requires lime and other chemical ingredients such as silica, alumina, iron, and magnesia. Quarries for cement materials are typically developed in limestone containing sufficient interbedded shales to provide the required accessories to the lime. Deposits of limestone are marginally economic (Class 2) within the ROI. The Niobrara Formation provides nearly the appropriate mix of materials and is the source of material for the cement plants in the region. The Pierre and Mowry shales provide material to supplement chemical deficiencies which may exist in the Niobrara. These geologic units are generally exposed for quarrying along both flanks of the Laramie Mountains and the east flank of the Front Range (Figure 2.6.3-2).

2.6.3.2.2 Gypsum

Gypsum, used in wallboard, also occurs in the upturned sediments flanking the mountains. Gypsum has been rated as a Class 2 resource, marginally economic (Figure 2.6.3-2).

2.6.3.2.3 Fill Materials

Engineered fills may be required to support planned construction and may require a full range of characteristics. Both cohesive and noncohesive materials are available in the area, ranging from high plasticity clay to sandy gravel. The active clay, bentonite, is also present throughout the area.

2.6.3.3 Oil and Gas

Production of oil and gas from the northern Denver Basin is limited to Cretaceous units, i.e., the sandstone members of the Pierre Shale through the basal Cloverly Formation (Wyoming Oil and Gas Conservation Commission 1981). Oil production from fields in western Nebraska is entirely from the Dakota Group (Nebraska Oil and Gas Commission 1983). Figure 2.6.3-2 shows the location of producing oil and gas fields in the ROI as of October 27, 1983 (Petroleum Information Corporation 1983a, b, c).

In the greater Denver Basin to the south and in the Powder River Basin to the northwest, Paleozoic units have recorded production, and several Paleozoic formations of the northern Denver Basin may have petroleum potential (Sonnenberg and Weimer 1981). Drilling in the northern Denver Basin has only penetrated down to the Cretaceous section in the vast majority of holes, so detailed information about the Paleozoic section is not available. Fossil fuel resources in the Paleozoic section are speculative. Presently, the entire northern Denver Basin is leased for oil and gas exploration and all of the basin must be considered to have hypothetical oil and gas resources.

Traps within the Cretaceous units are both structural and stratigraphic. Structural traps are the predominant type on the steep west flank of the basin and are generally well defined. Stratigraphic traps are the predominant type on the gentle east flank of the basin and are far more subtle and difficult to define.

2.6.3.4 Uranium

Uranium occurrences are scattered through several stratigraphic units in the Upper Cretaceous and Tertiary rocks of the northern Denver-Julesburg Basin, but the only concentrations of uranium with demonstrated potential for commercial development are in the Cretaceous Fox Hills Sandstone and lower Laramie sandstones in Weld County, Colorado. Deposits present in these units have been brought into production (Kirkham and Ladwig 1980). One uranium lease was present on state land in Laramie County (Section 36, T16N, R67W) as of December 1, 1982 (Figure 2.6.3-2). Since these potentially uraniferous stratigraphic units are present in the northern Denver-Julesburg Basin, a speculative uranium resources rank is assigned to the part of the study area where the projected uraniferous section lies at less than 1,000 foot depth. A 1,000 foot depth is estimated to be the deepest level where in situ solution mining might be considered economic in the present market. The presently subeconomic Colorado deposits are shallower.

Surface and airborne radiometric surveys of the study area, performed by the Department of Energy (DOE) as part of the National Uranium Resource Evaluation Program, identified numerous low-level uranium anomalies associated with groundwater surfacing in Late Tertiary units. The DOE surveys only tested the Cretaceous units in the Colorado part of the Denver-Julesburg Basin; however, the same Cretaceous units are present in the Wyoming portion of the basin (Geometrics 1978, Griffin and Warner 1981, Trexler 1978, Union Carbide 1980).

Bard (1982) describes a uranium exploration target, based on ground-water geochemistry, in Scotts Bluff and Banner counties, Nebraska, south of the North Platte River in the White River Group.

2.6.3.5 Coal

Historic production from the Denver Basin is over 130 million tons, all from northern Colorado (Kirkham and Ladwig 1980). Cumulative coal and lignite production through December 1979 for Weld and Larimer counties is about 65,881,085 short tons and 54,611 short tons, respectively. No Nebraska or Wyoming production is known. The only known producing coal mine in the northern Denver Basin is the Keenesburg Mine located a few miles north of Keenesburg, Colorado, and operated by the Adolph Coors Company. They plan to produce 500,000 tons per year(T/yr) (Kirkham and Ladwig 1980). Coal in the basin is in the Upper Cretaceous-Lower Paleocene Laramie Formation (Lance Formation equivalent). The coal-bearing section lies in the lower portion of the formation and consists of numerous thin coal and lignite seams interbedded with siltstone, sandstone, claystone, and shale. The coal occurs as lenticular, discontinuous seams, and the maximum thickness of Laramie Formation coals in the Wyoming part of the Denver Basin appears to be about 5 feet (Kirkham and Ladwig 1980). On the eastern flank of the basin where these coals are at shallower depth, their grade ranges from sub-bituminous to lignite. No economic potential was assigned to these coals where they are deeper than 500 feet in the basin, and only speculative potential can be given to the coals projected to be less than 500 feet pending more detailed data (Figure 2.6.3-2). The 500 foot depth is based on the poor quality of coal and thin seams in a remote-market area. Some potential may exist for in situ coal gasification in the Denver Basin, but there are no known gasification projects going on at this time.

2.6.3.6 Geothermal Resources

The nearest producing geothermal resource area is located about 380 miles to the south of the DA near Los Alamos, New Mexico, where a number of geothermal wells have been successfully completed. The closest area classified as being a potential geothermal resource is in the Dakota Group of western Nebraska (NOAA 1982, Figure 2.6.3-2). The Dakota geothermal reservoir satisfies the USGS requirements for low temperature geothermal resources (Reed and Sorey 1981). Three thermal wells have been drilled, one each in Scotts Bluff, Banner, and Kimball counties, with respective temperatures of 80°C, 70°C, and 70°C, at depths between 4,461 and 5,051 feet.

2.6.3.7 Base and Precious Metals

Historic production of base and precious metals and mining districts are shown in Figure 2.6.3-2. As of October 1982 none of these mines were currently in production or development, though most of the historic mining areas are still held under claims and are still being prospected. For this study, mining districts were considered to have speculative resources, and subeconomic to marginally economic reserves were considered in mines with historic production. No attempt has been made to assess current claim status in the Laramie Range, but the Bureau of Land Management (BLM) records show no current mining claims east of the range front in Laramie County as of October 1982.

No active base or precious metal production is reported in western Nebraska (Burchett and Eversoll 1983).

2.6.4 Soil Resources

This section is concerned with the agricultural and erosional characteristics of the soils in the DA. The agricultural properties of soils are estimated by the land capability classification system used by the SCS.

A general determination of baseline wind and fluvial erosion rates, based on composite soil characteristics, was done because of the overall similarity in the characteristics of soils in eastern Laramie County and along the potential cable routes in southern Goshen County, Wyoming, and Scotts Bluff and Banner counties, Nebraska.

2.6.4.1 General Soil Conditions

Soil classification within the ROI is based on a system used by the SCS (1975a). This system groups soil series into associations based on similar characteristics.

Based on available data, the soils located in areas of potential disturbance, such as the cable routes in eastern Laramie and Goshen counties, Wyoming and western Nebraska, and construction sites located on F.E. Warren AFB, should include the soil series listed in Table 2.6.4-1.

For the convenience of describing baseline conditions, the soils evaluated within the ROI were loosely grouped into two areas: Area A soils (the eastern Laramie County soils) and Area B soils (the soils of Scotts Bluff and Banner counties, Nebraska, and southern Goshen County, Wyoming).

2.6.4.2 Agricultural Properties

Properties that affect the suitability of a soil as a plant growth medium include moisture and nutrient retention capability, depth, workability, and topography. Other phenomena (e.g., climate) have major influences on soil formation rates and the capability of a region to produce agricultural products.

The natural vegetation within the area is grass and shrub. The grasses are considered to be an excellent feed source for cattle and sheep. All of the soils have the ability to produce these native grasses and are considered to

Table 2.6.4-1

SOIL SERIES LIKELY TO BE ENCOUNTERED IN AREAS OF POTENTIAL GROUND DISTURBANCE

	County			Construction Sites
Soil Series	Laramie[1]	Goshen[2]	Scotts Bluff and Banner[3]	F.E. Warren[4]
Albinas	x			x
Alliance			x	
Altvan	x			x
Anselmo		x		
Ascalon	x			x
Bankard			x	
Bayard	x			
Bayard Varient	x			
Bordeaux		x		
Bridget			x	
Canyon			x	
Creighton		x		
Dix	x			x
Dunday		x		
Dwyer		x		
Epping			x	
Glenberg		x	x	
Heldt		x		
Kim		x		
Manter	x	x		
Merden	x			
Merden Varient	x			
Mitchell	x	x	x	
Norka		x		
Nucla	x			
Orella		x		
Otero	x		x	
Rosebud		x	x	
Sarben			x	
Tassel	x			
Trelona		x		
Treon	x			
Valent	x		x	
Valentine		x		
Vetal	x			
Yockey			x	

Notes: 1 SCS 1982b
2 SCS 1971
3 SCS and Conservation and Survey Division 1981
4 USAF 1975

be a valuable resource. Although the majority of the land in Laramie County is covered by natural plant species, much of the land is suitable, with proper management, for the production of field crops. In contrast, lands in Nebraska and Goshen County, Wyoming are more heavily cultivated. A convenient scale for estimating the suitability of a soil to produce field crops is the land capability classification.

The SCS defines eight land capability classes ranging from Class I soils which have slight limitations on usage to Class VIII soils which have limitations that nearly preclude their use for commercial crop production (SCS 1975a). The limitations can take any of several typical forms such as shallowness, droughtiness, climate, and erosiveness. Within the ACSs where sufficient data for such an evaluation exist, the predominant limitation for soils is susceptibility to erosion.

In western Laramie County only general soils data exist. However, based on the general information it is suggested that the majority of the soils in the area would be in capability Classes II through VI with the primary limitation being susceptibility to erosion. Some soils could be shallow or droughty. There are no data available to suggest the presence of any Class I soils in the area. Some Class III soils have the potential to be Class II soils if irrigated.

Soil characteristics on F.E. Warren AFB indicate that the dominant classes are II through VI and that the primary limitation is susceptibility to erosion. There are no data available to suggest the presence of Class I soils in the area and some Class III soils may have the potential to be Class II soils if irrigated.

Based on the preliminary soils maps for eastern Laramie County (SCS 1982b) there are no Class I soils in the soil survey area. Some soils are Class II if irrigated. The majority of soils in eastern Laramie County are Class III with the predominant limitation being susceptibility to erosion. These soils are considered to be suitable for dryland wheat farming and a variety of other crops when irrigated. All soils in the area are generally suitable for native grasses which provide a feed source for cattle and sheep.

Other than "shallow" or "droughty or shallow" soils, the soils within the area of eastern Laramie County generally have a loamy surface layer (A horizon) and a sandy clay loam subsoil (B horizon). If managed properly to avoid excessive erosion, these soils are considered excellent plant growth media. The selection of crops in the area is restricted due to the semiarid climate and the high elevation of the area (6,200-6,900 feet above mean sea level) tends to shorten the growing season and could possibly preclude the planting of some crops.

The soils of southern Goshen County, Wyoming, and western Nebraska along the proposed cable routes are primarily Class III soils with nearly all of the soil cropped in wheat. These soils have the potential to be Class I if irrigated. The main limitation of these soils is susceptibility to wind erosion and lack of natural moisture. Smaller areas become Class II if irrigated because of problems controlling water and maintaining fertility.

2.6.4.3 Potential Wind Erosion

2.6.4.3.1 Introduction

As stated in Section 2.6.4.1, the soils within the ROI may be loosely grouped; those of eastern Laramie County (Area A), and those of Scotts Bluff and Banner counties and southern Goshen County (Area B). The generally uniform soil types and erosion characteristics of the two areas allow for a general treatment. An evaluation of baseline wind erosion potential has been made for composite soil conditions in eastern Wyoming and for typical soils along the cable routes in southern Goshen County, Wyoming and western Nebraska.

The following sections present the calculations and results for establishment of the various existing conditions pertaining to potential wind erosion.

2.6.4.3.2 Baseline Soil Conditions

Baseline soil conditions were delineated from both detailed and general SCS soil maps. The DA portion of Laramie County is characterized by loams, silty clay loams, and loamy sands. The soil profile can generally be described as having loamy topsoil (A horizon) from 4 to 9 inches thick, underlain by the B horizon of sandy clay loam about 2 feet thick which gradually grades into parent material (C horizon), typically gravelly sand or loamy sand.

The soils of the DA and the proposed cable routes in western Nebraska and southern Goshen County, are mainly loams, sandy loams, silty loams, and very fine sandy loams. The soil profile can generally be described as having loamy 10-inch thick A horizon, a 14-inch thick heavy loam to a basal 9-inch thick silt loam B horizon, and a silt loam C horizon at a depth of 35 inches.

2.6.4.3.3 Wind Erosion Equation

The evaluation of wind erosion potential is based upon the Wind Erosion Equation developed by the SCS (1982a). This equation states that E is a function of I, K, C, L, and V where:

E = soil loss in T/acre/yr;
I = soil erodibility;
K = soil ridge roughness;
C = climatic factor;
L = affected length; and
V = vegetative cover.

Further details on the variables used in the Wind Erosion Equation and an example calculation are presented in Appendix A.

Wind erodibility indices (I) were obtained from the Technical Notes on the Wind Erosion Equation (SCS 1982a). An erodibility index of 65 for the Area A soils was calculated as a weighted average of the soil types occurring there. An erodibility index of 56 was calculated for the Area B soils, where the proposed cable routes are located.

Factor K, the soil ridge roughness factor, was estimated from charts developed by the SCS (1982a). For the analysis, it was assumed that furrows are approximately 2 feet apart and about 8 inches deep for moldboard plowing. These assumptions yield a K-value of approximately 0.8 for plowed fields. For growing or combined wheat and rangeland conditions, a value for K of 1.0 was used.

The climatic factor (C) was normalized to Garden City, Kansas, and after considering the persistence of erosive forces in the direction of prevailing winds (SCS 1982a), was calculated to be 80 for the Area A soils and 60 for the Area B soils.

For the baseline affected length factor (L) it was assumed that cropping strips are oriented north-south in accordance with general agricultural practice in the region. The prevailing wind direction is from the northwest. Farm strips generally range between 116 and 165 feet wide (SCS 1982a), so an assumed width of 150 feet was used in the analysis. From the alignment chart (SCS 1982a), an unsheltered distance of 212 feet was obtained for the field width along the prevailing wind erosion direction.

Good vegetative cover on the land surface is the most effective way to control wind erosion. Protection of the soil by vegetative matter depends upon the kind, quantity, and orientation of the vegetative cover. These three factors are expressed as the baseline vegetative cover factor (V). The factor V was analyzed by evaluating various crops raised in the site-specific area of influence using charts and tables presented by SCS (1982a). The output from this analysis is as follows:

Wheat:	Assume small-grain growing at 400 pounds per acre per year (lb/acre/yr)
Rangeland:	Assume various native species exist growing at 1,400 lb/acre/yr (SCS 1982c)

The following values have been used in the calculation of baseline wind erosion losses for the two areas:

Values	Area A Soils	Area B Soils
Soil Erodibility (I)	65	56
Soil Ridge Roughness (K)		
Rangeland	1.0	1.0
Growing Wheat	1.0	1.0
Combined Wheat (stubble)	1.0	1.0
Plowed Wheat	0.8	0.8
Climatic Factor (C)	80	60
Affected Length (L)	212	212
Vegetative Cover (V) (in small-grain equivalents)		
Rangeland	5,200	5,200
Growing Wheat	800	800
Combined Wheat (stubble)	800	800
Plowed Wheat	250	250

The estimated percent of any year meeting various vegetative conditions are summarized as follows:

Vegetative Condition	% of Year
Rangeland	100
Growing Wheat	46
Combined Wheat (stubble)	4
Plowed Wheat	50

These percentages reflect the local practice of "summer fallowing" where alternate strips are planted in about August, harvested about June, and left bare for about 14 months after harvesting. Thus, an average of about 6 months plowed for the croplands is appropriate.

The estimated percentage breakdown of agricultural land utilization for the two areas is as follows:

Area	% Range	% Crop
A	56	100
B	0	100

The estimated soil loss for baseline conditions (E_{site}) is calculated by:

$$E_{site} = (E_{veg} \cdot \% \text{ area} \cdot \% \text{ year}),$$

and is summarized as follows:

AREA	Rangeland (E_{veg} %A %yr)	+	Growing Wheat (E_{veg} %A %yr)	+	Combined Wheat (E_{veg} %A %yr)	+	Plowed Wheat (E_{veg} %A %yr)	=	E_{site} (T/acre/yr)
A	(0.1 56 100)	+	(7.0 44 46)	+	(7.0 44 4)	+	(16.3 44 50)	=	5.2
B	(0.1 0 100)	+	(3.1 100 46)	+	(3.1 100 4)	+	(5.0 100 50)	=	4.1

2.6.4.4 Potential Water Erosion

2.6.4.4.1 Introduction

The baseline study for potential water erosion has been conducted on a basis similar to that for potential wind erosion. The generally uniform soil types and erosion characteristics of the soils in the two areas analyzed (eastern Laramie County - Area A and southern Goshen, Scotts Bluff, and Banner counties - Area B) allows for a general treatment.

A limitation to the prediction of potential water erosion for the baseline values is the use of empirical algorithms for the calculations of unit soil loss. Although the state-of-the-art techniques are based on current research data, it has been necessary to make some extrapolations and approximations.

The USLE makes quantitative predictions only for construction-site sized plots (i.e., for slope lengths less than 400 feet and for gradients between 3 and 18 percent). Quantitative predictions of the soil loss rates for a project require the addition of soil losses from all construction-site sized plots required to cover the entire region. Soil loss rates vary by an order of magnitude over an area the size of a project. Often a few small areas contribute the majority of the soil loss. When extended to large areas, the USLE becomes at best a qualitative model of the erosion process. The USLE does not take into account the deposition of soil eroded from other areas within the project.

2.6.4.4.2 Universal Soil Loss Equation

The evaluation of water erosion potential is based on the USLE which reads: $A = R \cdot K \cdot L \cdot S \cdot C \cdot P$ where A is the computed soil loss from sheet and rill erosion in T/acre/yr, and

R = the rainfall factor;
K = the soil erodibility factor;
L = the slope-length factor;
S = the slope-gradient factor;
C = the crop management factor; and
P = the erosion control factor.

Further details on the variables used in the USLE and example calculations are presented in Appendix A.

The rainfall factor, R of the USLE, reflects the energy intensity of rainfall and its total annual effect on erosion of soil particles. R factors are calculated from the isoerodent contour plot contained in SCS (1975b). Values must be extrapolated and averaged from a map of the United States with contours in Laramie County of R=37.5 east of Cheyenne and 25 near Cheyenne. Values for western Nebraska were averaged from several sources. The values given below are used for all calculations for the respective areas:

Areas	R Factor
A	31.0
B	40.0

For the purpose of estimating baseline conditions, an estimate was made of the K values which best represent the two soil areas. Soil types were identified using published data (SCS 1982b, 1971, 1968) and then K values were deduced directly from tables prepared by the SCS.

The K value for the Area A soils is 0.32. The K value was estimated as 0.37 for the Area B soils.

For convenience, factors L and S of the USLE are combined into a single topographic factor LS which is usually obtained from graphs. Values of LS for slopes of less than 3-percent gradient and slope lengths greater than 400 feet constitute extrapolations of the formula beyond the range of research data and should be used with caution.

Slope gradients for the soils analyzed have been determined from topographic maps. The average slope for Area A soils is 0.5 percent and about 1.0 percent for the Area B soils.

The average slope is semi-quantitatively deduced considering the relative proportions of area covered by draw-slopes and rangelands. Slope lengths for the baseline conditions are estimated from topographic maps to be 2,000 feet. This distance represents average lengths of sheet and rill paths and does not include erosion paths.

The LS factors for the baseline conditions are estimated from the slope-effect graph to be 0.33 for Area A soils and 0.32 for Area B soils.

Factor C is related to land use, and rigorous calculation of soil loss should consider corresponding C, K, and LS factors for each land parcel. From the Laramie County Land Use Map, prepared by the USGS (1982), estimates have been made of the percentage distribution of cropland and rangelands for the two areas. These are:

Areas	% Distribution	
A	Rangeland	56
	Cropland	44
B	Cropland	100

C factors are calculated from SCS, 1975b on the basis of the assumptions and assumed mitigations listed in Section 3.2. In addition, all C factors for the baseline study assume the vegetative cover at the surface is grass, grass-like plants, decaying compacted duff, or litter at least 2 inches deep.

For these conditions, C factors are estimated to be 0.024 in all cases. Thus, no errors are introduced by the inability to consider site-specific land usage.

Factor P is assumed to be 1.0 in construction applications of the USLE. Erosion-reducing effects of terraces and diversion are accounted for by modifications to the LS factor. Contour strip-cropping is practiced for the non-irrigated cropland. For these areas with a land slope of 2.0 percent or less, a P value of 0.20 is assumed. This value is applicable to all cropland in the baseline study and cropland unaffected by construction or project operations.

Successive applications of the USLE are used to provide comparative soil loss estimates to help guide decisions concerning fluvial erosion effects and comparable benefits of alternative erosion control steps.

The following values have thus been used in the calculation of the baseline erosion losses for the two areas analyzed:

Factors		Area A Soils	Area B Soils
Rainfall Factor	(R)	31.0	40.0
Soil Erodibility	(K)	0.32	0.37
Slope Effect	(LS)	0.33	0.32
Management	(C)	0.024	0.024
Control	(P)	0.20	0.20
A (T/acre/yr)		0.02	0.02

These values of erosion rates are very low, and except for any significant changes in land cropping management or erosion control practice (which is unlikely), the future trend is expected to be the same.

3.0

ENVIRONMENTAL CONSEQUENCES, MITIGATION MEASURES, AND UNAVOIDABLE IMPACTS

3.0 ENVIRONMENTAL CONSEQUENCES, MITIGATION MEASURES, AND UNAVOIDABLE IMPACTS

3.1 Analytic Methods

3.1.1 Geologic Hazards

As described in Section 2.5.1, the baseline data on potential geologic hazards (i.e., regional seismicity, faulting, subsidence, landsliding, and liquefaction) were obtained and analyzed within the Region of Influence (ROI). The analytic methods used to evaluate the environmental consequences of potential geologic hazards were essentially the same as those used to evaluate existing conditions. In many instances the methods used to analyze existing conditions removed any concern for potential impacts. For example, the analyses indicated that subsidence and liquefaction were not issues because the conditions necessary for their occurrence were either not present or of very limited extent with no documented instances of these hazards in the Deployment Area (DA). Landsliding was not considered an issue because of the low relief on the areas proposed for the project and the small number of known landslides.

Regional seismicity and potential faulting were considered possible issues in terms of the impact of the resource on the project. Since the level of impact definitions and analyses are only concerned with the impact of the project on the environment, regional seismicity and faulting were classified as safety issues and presented in Section 1.6.10.4.3 of the Final Environmental Impact *Statement* (FEIS).

3.1.1.1 Baseline Future - No Action Alternative

Analytic methods for the Baseline Future - No Action Alternative are the same as described in Section 2.5.1.

3.1.1.2 Proposed Action

Analytic methods used in assessing geologic hazards are the same as discussed in Section 2.5.1. Section 3.1.1 describes how the level of impact definitions are applied to geologic hazards.

3.1.2 Energy and Mineral Resources

3.1.2.1 Baseline Future - No Action Alternative

The analytic methods used for assessing the No Action Alternative are the same as those used for existing environmental conditions discussed in Section 2.5.2.

3.1.2.2 Proposed Action

Methods outlined in Section 2.5.2 were supplemented with additional data concerning preliminary estimates of project requirements. These data were compared to estimates of available resources within the ROI.

3.1.3 Soil Resources

3.1.3.1 Baseline Future - No Action Alternative

Analytic methods used for the No Action Alternative are the same as those used for assessing existing environmental conditions and are discussed in Section 2.5.3 and Appendix A.

3.1.3.2 Proposed Action

The analysis of wind and water erosion was conducted using the procedures discussed in Section 2.5.3 and Appendix A. The analyses were site specific because of the limited areas (such as the cable routes) which would be disturbed during project construction. With all other variables being equal, the K factor of the Universal Soil Loss Equation (USLE) and the I factor of the Wind Erosion Equation are the primary limiting variables. Therefore, the primary approach taken for the analysis of project-induced soil erosion was to evaluate the soil loss in areas containing soils with the highest susceptibility to erosion and to compare these values to estimated soil formation rates for baseline conditions.

3.2 Assumptions and Assumed Mitigations

3.2.1 Assumptions

For aggregate resources, it was assumed that aggregate supplies would be located within or immediately adjacent to the ROI. This assumption is justified by the large natural deposits of the resource within this area which are close enough to be economically available.

In the evaluation of wind and water erosion potential, several assumptions were necessary. These assumptions are detailed in Section 2.5.3, Analytic Methods, and Appendix A.

3.2.2 Assumed Mitigations

Assumed mitigations consist primarily of procedures or policies normally employed during the construction phase of a large project. The assumed mitigations presented in this section were used to minimize project impacts and are included in the impact analysis. Assumed mitigation measures for the geologic resource subelements include:

- o Aggregate - No assumed mitigations are required for aggregate resources.

- o Soil resources - Assumed mitigations consist primarily of procedures normally employed during the construction phase of a large project and include the Defense Access Roads (DARs) and cable route construction activities and any project-induced ground disturbance in the DA and on F.E. Warren AFB. They include:

  - strip and stockpile topsoil in areas requiring grading, other than for permanent construction, and in areas where excavated materials will be disposed, and then replace the topsoil when grading or disposal is complete;

- revegetate or recrop disturbed areas as soon as possible;

- utilize properly designed erosion control practices that meet state regulations, such as mulching, in any areas required to be left disturbed for extended periods of time. This will minimize erosion, including erosion along major drainages;

- avoid locating cable routes across steep terrain (>6%). Where this is not possible, minimize the number of steep, long (>200 ft) segments oriented perpendicular to the slope;

- where possible, avoid soils that may be highly sensitive to project activity (tolerable soil losses less than 4 tons per acre per year [T/acre/yr]). Consult with local Soil Conservation Service (SCS) soil scientists prior to final selection of the cable route within the 1-mile corridor;

- sequence DAR and cable route construction, where practical, to minimize large continuously disturbed areas, especially those oriented parallel to the prevailing winds; and

- following construction, protect areas until new cover is well established, or the site is returned to desired use.

3.3 Level of Impact Definitions

3.3.1 Geologic Hazards

The level of impact definitions for geologic hazards are:

- o Negligible Impact - The project would not measurably affect the projected baseline rate of natural geologic processes.

- o Low Impact - The project would measurably affect the projected baseline rate of the natural geologic processes, but the acceleration would be very limited, and the associated effects or hazards would be slight.

- o Moderate Impact - The project would measurably affect the projected baseline rate of the natural geologic processes and the acceleration would be sufficient to produce noticeable geologic hazards requiring mitigation alternatives.

- o High Impact - The project would greatly accelerate the projected baseline rate of the natural geologic processes producing geologic hazards which have potentially lasting and possibly detrimental effects requiring difficult mitigation alternatives.

The justification for these definitions is as follows:

- o The project can initiate or accelerate existing geologic processes which can impact the ROI and, in the extreme, affect the performance of the project. An example might be road grading and construction creating severe erosion and landsliding within and beyond the limits of the project.

- The impact of the project on the areal geology represents the geologic considerations most useful for evaluating environmental effects from this project. A project impact is evaluated by the relative rate of increase above the baseline geologic processes. The least effect would be that the project introduces no measurable rate of increase in the geologic processes. The other extreme would be that the project impacts are so great that the accelerated geologic processes would affect the performance of the site and/or would impact the surrounding areas.

3.3.2 Energy and Mineral Resources - Aggregate Resources

As previously stated, the only subelement of energy and mineral resources impacted by the project is aggregate resources. The following level of impact definitions are designed accordingly. The level of impact definitions are based on the total estimated reserves within and adjacent to the ROI. The potential impacts of project aggregate use are also assessed via the production capacity and capacity utilization within the region in Section 3.1.4, Construction Resources, in the FEIS.

- Negligible Impact - Project demand will be less than 1 percent of estimated reserves.
- Low Impact - Project demand will be between 1 and 10 percent of estimated reserves.
- Moderate Impact - Project demand will be between 11 and 20 percent of estimated reserves.
- High Impact - Project demand will be greater than 20 percent of estimated reserves.

The justification for these definitions is based upon the relationship between project demand and currently identified aggregate reserves. Threshold values for each impact category are arbitrarily defined but do reflect the relationship between project demand and baseline conditions. The effect of the project is on the availability of aggregate to off-project users in the ROI..

3.3.3 Soil Resources

The level of impact definitions for soils are:

- Negligible Impact - The project would induce erosion at an undetectable rate.
- Low Impact - The project would induce erosion at a rate less than the soil formation rate.
- Moderate Impact - The project would induce erosion at a rate approximately equal to the soil formation rate.

- o High Impact - The project would induce erosion at a rate greater than the soil formation rate.

The justification for these definitions is based on tolerable soil losses developed by the SCS. The tolerable soil loss is the maximum average annual soil loss that will allow continuous cropping and maintain soil productivity without requiring additional management inputs. The maximum soil erosion rate is offset by the theoretical maximum rate of soil development which will maintain an equilibrium between soil losses and gains. Tolerable soil losses for a particular soil series are reported in soil survey reports and are generally available for any area where soils have been mapped to the series level. Although the tolerable soil loss is not a strict representation of the rate of weathering of parent material, it is a reasonable guide to the rate at which the productive soil profiles are formed. The soil formation rate as used in the impact definitions can be taken to be analogous to the tolerable soil losses defined by the SCS. As such, these definitions of impact are easily quantified for projects in areas where soils have been mapped.

3.4 Significance Determination

3.4.1 Geologic Hazards

For the level of a geologic hazard to be considered significant, one of the following conditions must be met:

- o The project would initiate new geologic processes requiring special mitigation measures within the design life of the facility; and

- o The project would accelerate existing geologic processes requiring mitigation within or beyond the design life of the facility.

For geologic hazards to be considered a significant environmental impact, the project would have to cause an increase in the level of historic activity to the point where adverse impacts would be created.

3.4.2 Energy and Mineral Resources

For the level of impact on aggregate resources to be considered significant, there must be a depletion in regional resource availability that would result in a long-term decrease in revenue to the regional economy.

3.4.3 Soil Resources

The significance criterion for soil resources is based on a comparison of the rate of soil erosion to the rate of soil formation in undeveloped areas of the ROI. The impact to soil resources is considered significant when the rate of soil erosion is greater than the rate of soil formation, producing a loss in agricultural productivity of the affected area.

3.5 Environmental Consequences of the Proposed Action and No Action Alternative

3.5.1 Geologic Hazards

3.5.1.1 Baseline Future - No Action Alternative

Anticipated future trends for geologic hazards are not expected to deviate from past levels.

3.5.1.2 Proposed Action

Evaluation of existing data has shown that the project will produce no additional geologic hazards.

3.5.2 Energy and Mineral Resources - Aggregate Resources

3.5.2.1 Baseline Future - No Action Alternative

For aggregate resources, anticipated future trends without the project would reflect historic responses to market demands. A normal economic growth would result in continued low-level use for aggregate.

3.5.2.2 Proposed Action

A low impact at the local level is expected for aggregate resources. Concrete and road building and maintenance requirements would provide demands for aggregate. Sufficient quantities of sand and gravel, and crushed rock are available to meet the additional project and project-element alternative demands.

Preliminary estimates of project construction aggregate demands are about 4.6 million tons or approximately 2.6 million cubic yards (cy). Such a demand for aggregate would produce some direct or indirect impacts as production quantities are expanded. These impacts would last until the completion of the project construction and would influence areas within economic haul distances of the project. A reduced, minimal, ongoing need for aggregate for road maintenance will continue throughout the life of the project.

The low impact from aggregate resources is not significant as there is no depletion of the regional resource availability that would result in a long duration decrease in revenue to the regional economy and therefore no decreases in revenue to the economy of the ROI.

3.5.3 Soil Resources

3.5.3.1 Baseline Future - No Action Alternative

The baseline conditions of wind and water soil erosion discussed in Section 2.6.4 would continue for the foreseeable future.

3.5.3.2 Proposed Action

The soil erosion analyses are for those agricultural areas subject to Air Force contracted construction of the proposed cable routes and alternatives and facilities on F.E. Warren AFB, and are based on application of all the assumed mitigations presented in Section 3.2.2. Should other construction take place without these assumed mitigations, total soil erosion rates would be higher (refer to Water Resources EPTR, Section 2.6.3).

A low impact at the site level is anticipated for potential wind and water erosion. Some areas will be permanently or temporarily disturbed and it is anticipated that disturbed areas would be either revegetated, returned to cropland use, mulched, or covered by some nonerodible material (i.e., paving, building, etc.). The low impact is expected to last during any construction phases and until the disturbed areas are either revegetated, returned to cropland, or built upon.

3.5.3.2.1 Cable Routes - Wind Erosion Potential

The potential wind erosion is directly related to the amount of protective cover and the size of the area considered. Most of eastern Laramie County and western Nebraska is dry land farmed in wheat. The soils of western Nebraska and southern Goshen County along the proposed cable routes are cropped extensively in wheat and are more susceptible to wind erosion than those of eastern Laramie County. Areas disturbed within the project area could similarly be subject to significant erosion at the site level without the measures assumed in Section 3.2.2.

As mentioned in Section 3.1.3.2, analysis was conducted along the cable route exhibiting the highest potential for wind erosion. The analysis was accomplished with the analytic method presented in Section 2.5.3.2 (Potential Wind Erosion) but was site specific. The cable network corridor determined to have the highest wind erodibility factor (I=220) is route PD1 in northeast Laramie County. The I factor of 220 was determined from soil types mapped by SCS (1982b).

The soil ridge roughness factor (K), was estimated from SCS (1982b). It was assumed that disturbed areas would not be smooth but rough as a result of construction activities. These assumptions yield a K value of approximately 0.8.

The climatic factor (C) of the wind erosion equation was obtained from SCS (1982a) and was calculated to be 80 for route PD1.

For the affected length (L), a value of 20 feet was assumed for the width of the disturbed area along the cable route.

Good vegetative cover or mulch on the land surface is the most effective way to control wind erosion. These considerations are expressed as the vegetative cover factor (V). For the analysis, a straw mulch cover spread at 2,000 pounds per acre (lb/acre) was assumed for disturbed areas. This V factor would provide 70 percent ground cover with no appreciable canopy.

The estimated soil loss (E) along PD1 based on the above calculations and assumed values is 0.9 T/acre/yr. This estimated soil loss may be reduced even further by application of additional mulch.

This value is very low and when compared to the SCS's estimated tolerable soil loss as discussed in Section 3.3.3 (2 T/acre/yr for the soils along route PD1), a low and not significant impact results.

3.5.3.2.2 Cable Routes - Water Erosion Potential

Moving water is another force causing soil erosion but is not considered a serious problem in southeastern Wyoming, primarily because of the climatic considerations of the region. However, certain unprotected areas, primarily cropland, may be seriously affected by water erosion without the mitigation measures assumed in Section 3.2.2. Similarly, disturbed areas within eastern Laramie County and western Nebraska could be seriously affected by water erosion if not properly protected.

An analysis was conducted along the cable route selected as having the highest susceptibility to water erosion. Portions of route SC2 are located in a Mitchell silt loam which has a K factor (soil erodibility) of 0.43. The analysis was done with the analytic methods discussed in Section 2.6.4.4 (Potential Water Erosion).

The rainfall factor (R) was estimated as 40 from the isoerodent contour plot contained in SCS (1975).

The topographic factor (LS) of 0.32 was obtained from SCS (1975b) using a slope length of 2,000 feet and slope gradient of 1 percent.

The crop management factor (C) was calculated from SCS (1975) on the basis of the assumptions listed in Section 3.2.2 (i.e., straw mulch applied at 2,000 lb/acre). These assumptions yield a C value of 0.03.

As stated in Section 2.6.4.4.2, the erosion control factor (P) is assumed to be 1.0 in construction applications of the USLE.

The calculated soil loss is 0.17 T/acre/yr. This value is very low and when compared to the SCS's estimated tolerable soil loss, 5 T/acre/yr for the Mitchell silt loam, a low and not significant impact occurs.

3.5.3.2.3 F.E. Warren AFB - Erosion Potential

Soil types at F.E. Warren AFB have been mapped to the series level (USAF 1975) and are very similar to the soil associations mapped in eastern Laramie County. The soil types at F.E. Warren AFB in the proposed areas of construction are one of the following soil series: Altvan, Altvan/Dix complex, Ascalon, or Albinas (USAF 1975). The Altvan and Albinas soils have the highest water erodibility (K=0.32) and the Ascalon soil has the highest wind erodibility factor (I=86).

A potential wind erosion analysis for the soil at F.E. Warren AFB with the highest erodibility (I=86) yields an estimated soil loss of 1.5 T/acre/yr for smooth surfaces (K=1.0) and 1.1 T/acre/yr for rough surfaces (K=0.8). The C and V variables for this analysis were the same as for the wind erosion analysis for Laramie County, i.e., C=80, V=2,000. The length factor (L) was taken as 2,000 feet as this is the approximate longest exposed length of any of the proposed construction sites.

The potential water erosion analysis using the most erodible soil at F.E. Warren AFB (K=0.32) yields a potential soil loss of 0.12 T/acre/yr. The analysis used the same values as those in the USLE cable route water erosion analysis, i.e., R=40, LS=0.32 (based L=2,000 feet and S=1 percent), C=0.03, and P=1.0.

These values are very low, and when compared to the SCS's estimated tolerable soil loss of 4 T/acre/yr (SCS 1982b), a low and not significant impact results. These erosion estimates include the application of the assumed mitigations discussed in Section 3.2.2.

3.6 Summary of Impacts

3.6.1 Impact Matrix

There are no project impacts on geologic hazards.

Aggregate resources are termed a low impact at the local level and negligible at the site and regional levels in the short and long term (Figure 3.6.1-1). Estimates have shown there are adequate reserves of aggregate within the ROI to satisfy project construction (short term) and road maintenance (long term) demands. However, the project would cause a change in capacity utilization and inventories of local suppliers. On a regional level, no measurable change in the capacity utilization rate would occur but regional supplier inventories could be affected depending on the rate of aggregate demanded.

Project impacts on soil resources are considered low and not significant at the site level for the short term as potential erosion could occur during project construction activities but would be minimal if assumed construction practices (Section 3.2.2) are observed. Assuming that the disturbed areas are revegetated, recropped, mulched, or built upon, no long-term consequences would result.

3.6.2 Aggregation of Elements, Impacts, and Significance

The overall impacts for geologic resources presented in Figure 3.6.1-1 are low and not significant at the site and local levels in the short term, and low and not significant at the local level in the long term. All other impacts, regional short term, and site and regional long term, are negligible and not significant.

These overall impacts have been developed through the following combinations of element and subelement impacts (Figure 3.6.1-1). No impacts were identified for geologic hazards. Only one subelement of energy and mineral resources, aggregate resources, was impacted by the project. Therefore, the level of impact for the subelement (aggregate resources) was directly assigned to the element level. Soil resources were only evaluated at the element level.

LEGEND		ADVERSE IMPACTS	SIGNIFICANT ADVERSE IMPACTS
LEVEL OF IMPACT*	LOW	○ (small)	● (small)
	MODERATE	○ (medium)	● (medium)
	HIGH	○ (large)	● (large)
POTENTIAL BENEFICIAL EFFECTS			(stippled box)
*MEASURE OF THE AMOUNT OF ENVIRONMENTAL CHANGE			

	PROJECT IMPACTS					
	SHORT TERM			LONG TERM		
	SITE	LOCAL	REGIONAL	SITE	LOCAL	REGIONAL
GEOLOGICAL RESOURCES	○	○			○	
Energy and Mineral		○			○	
Aggregate		○			○	
Soil Resources	○					

Note: elements and subelements of geologic resources (e.g., geologic hazards and landslides) not identified on this summary matrix have negligible project-induced impacts in either the short or long term.

GEOLOGIC RESOURCES SUMMARY IMPACT MATRIX

FIGURE NO. 3.6.1-1

Each area of consideration for level of impact, site, local, and regional, has only one assigned impact: soil resources at the site level; energy and mineral resources at the local level and nothing at the regional level. Therefore, the level of impact of the applicable element was directly assigned to the overall resource. Because there is only one level of impact for each overall impact area, aggregation was not necessary.

3.7 Mitigation Measures

Two potential mitigation measures will be considered for geologic resources. The first measure concerns aggregate resources and identifies the party responsible to implement, but not necessarily to pay for, the measure. The recommendation is that prior to determination of final aggregate source locations by subcontractors, an evaluation of all available sources within a similar economic haul distance be made and topographically high (ridge-forming) deposits be avoided where possible. The second measure concerns soil resources. The Air Force is considering an Agricultural Monitoring Program that includes the monitoring of soil erosion in agricultural/undeveloped areas subject to Air Force contracted construction.

3.8 Unavoidable Adverse Impacts

No significant unavoidable impacts are anticipated for geologic resources from the implementation of the project. However, there will still be some wind and water-caused erosion of soils regardless of construction controls; these may at times be greater than the Baseline Future - No Action Alternative (Section 3.5.3.1).

3.9 Irreversible and Irretrievable Resource Commitments

Aggregate is a nonrenewable resource and, therefore, its use for this project would result in an irreversible and irretrievable commitment of about 4.6 million tons of the resource.

3.10 The Relationship Between Local Short-Term Use of Man's Environment and Maintenance and Enhancement of Long-Term Productivity

Potential effects on geologic resources would be short and long term, with the demand for aggregate and soil erosion associated with the construction phase of the project. The continued use of aggregate for road maintenance throughout the operational (long-term) phase of the project should enhance average demands on the area suppliers in a positive manner. No known geologic hazards would be accelerated either in the short or long term.

4.0

GLOSSARY

4.0 GLOSSARY

4.1 Terms

Active Fault: a fault along which there is recurrent movement, usually indicated by small periodic displacements or seismic activity.

Aggregate: any of several hard, inert materials such as sand, gravel, or crushed stone, used for mixing with a cementing material to form concrete, mortar, or plaster; or used alone, as in railroad ballast or graded fill.

Algorithm: a fixed step-by-step procedure for accomplishing a given result.

Alluvial Fan: a body of stream deposits whose surface approximates a segment of a cone that spreads out downslope from the point where the stream leaves a mountainous area.

Alluvium: sediments deposited by a stream or running water.

Anticline: a fold, generally convex upward, whose core contains the stratigraphically older rocks.

Arch: a broad, open anticlinal fold on a regional scale.

Argillaceous: said of a rock or sediment composed of, or containing, clay-size particles or clay minerals.

Aseismic: an area or region that is not subject to earthquakes.

Attenuation: a reduction in the energy of seismic waves.

Badlands: intricately stream-dissected topography, characterized by a very fine drainage network.

Baseline: the characterization of an area under no-project conditions.

Base Metal: any of the more common and more chemically active metals, e.g., lead, copper, etc.

Bentonite: a soft, plastic, porous, light-colored rock composed essentially of clay minerals of the montmorillonite group which commonly has the ability to absorb large quantities of water accompanied by an increase in volume.

Body Wave: an earthquake wave that travels through the interior of the earth.

Cambrian: a period of the Paleozoic era extending from about 570 to 505 million years ago.

Cenozoic: an era of geologic time extending from about 65 million years ago to the present.

Cretaceous: the last period of the Mesozoic era, extending from about 144 to 65 million years ago.

Crystalline Rock: a rock consisting wholly of crystals or fragments of crystals.

Deformation: a general term for the process of folding, faulting, etc. of rocks as a result of various earth forces.

Design Life: the anticipated useful life of a facility.

Deterministic Process: a process in which there is, or is assumed to be, an exact mathematical relationship between the independent and dependent variables in the system.

Displacement: a general term for the relative movement of the two sides of a fault, measured in any chosen direction.

Dissected Topography: an area of land characterized by numerous valleys and gulleys caused by extensive surface erosion.

Disturbed Area: that specific land which has had its surface altered by grading, digging, or other activity related to construction.

Divide: the ridge marking the boundary between two adjacent drainage basins or dividing the surface waters that flow naturally in one direction from those that flow in the opposite direction.

Dolomite: a variety of limestone or marble rich in magnesium carbonate.

Earthquake: a sudden motion or trembling in the earth caused by the abrupt release of accumulated strain.

Eocene: an epoch of the Tertiary period extending from about 58 to 36 million years ago.

Epicenter: the point on the earth's surface directly above the focus of an earthquake.

Fault: a fracture or zone of fractures along which there has been movement of the sides relative to one another and parallel to the fracture.

Fault Plane: a fault surface that is more or less planar.

Fault System: two or more interrelated fault zones.

Fault Zone: a fault that is expressed as a zone of numerous small fractures.

Floodplain: the surface of relatively smooth land adjacent to a river channel which is covered by water when the river overflows its banks.

Fluvial (Fluviatile): of or pertaining to a river or rivers.

Fold: a curve or bend in rock strata.

Formation: a lithologically distinct, mappable rock body.

Geochemistry: the study of the distribution and amounts of chemical elements in minerals, rocks, water, etc.

Geologic Hazard: a naturally occurring or manmade geologic condition or phenomenon that presents a risk or is a potential danger to life and property.

Geomorphic: pertaining to the form of the earth's surface.

Geomorphology: the study of the earth's surface.

Geothermal: pertaining to the heat of the interior of the earth.

Group: two or more associated formations.

Gypsum: a widely distributed mineral consisting of hydrous calcium sulfate; chiefly used as a retarder in Portland cement and in making plaster of paris.

Holocene: the last epoch of the Quaternary period extending from about 10,000 years ago to the present.

Impact: an assessment of the meaning of changes in all attributes being studied for a given resource; an aggregation of all the effects, usually measured using a qualitative and nominally subjective technique.

Incised: said of a stream channel that has been downcut or entrenched into the land surface during, and because of, rejuvenation of the stream.

Induced Seismic Activities: a seismic activity which is either initiated or increased as a result of nontectonic processes, i.e., fluid injection or withdrawal, or reservoir loading.

Jurassic: a period of the Mesozoic era extending from about 208 to 144 million years ago.

Landslide: the downslope movement of soil and rock material en masse, under gravitational influence.

Lignite: a brownish-black coal that is intermediate between peat and sub-bituminous coal.

Limb: the sides of a fold.

Limestone: a sedimentary rock consisting chiefly of calcium carbonate.

Liquefaction: the transformation from a solid to a liquid state as a result of increased pore pressure and reduced effective stress.

Lithology: the physical character of a rock such as its color, hardness, mineral composition, and grain size.

Loam: a rich permeable soil composed of equal amounts of clay, silt, and sand, usually containing organic matter.

Loess: a typically buff-colored, wind-blown silt directly attributable to glacial outwash.

Magnitude (earthquake): a measure of the strength of an earthquake or the strain energy released by it.

m_b: body wave magnitude. An earthquake magnitude determined at large distances using the logarithm of the ratio of amplitude to period of body waves.

Mesozoic: an era of geologic time extending from about 245 to 65 million years ago.

Metamorphic Rock: a rock derived from preexisting rocks by changes from increased temperature and pressure and the chemical environment, generally at depth in the earth's crust.

Miocene: an epoch of the Tertiary period extending from about 24 to 5 million years ago.

M_L: local Richter earthquake magnitude. A measure of the strain energy released by an earthquake within 100 kilometers of the epicenter.

Modified Mercalli Intensity: an arbitrary measure of an earthquake's intensity based on the effect on people and structures. Ranges from I (not felt by people) to XII (damage nearly total).

Normal Fault: a fault in which the overlying side of the fault appears to have moved downward relative to the underlying side of the fault.

Oligocene: an epoch of the Tertiary period extending from about 36 to 24 million years ago.

Orogeny: the process by which mountains are formed.

Paleozoic: an era of geologic time extending from about 570 to 245 million years ago.

Pennsylvanian: a period of the Paleozoic era extending from about 320 to 286 million years ago.

Permafrost: any surficial deposit occurring in arctic, subarctic, and alpine regions in which a temperature below freezing has existed continuously for a long time.

Permeability: the property or capacity of a porous rock, sediment, or soil for transmitting a fluid.

Petroliferous: said of a geologic rock unit which contains oil and/or gas.

Physiographic Province: a region of which all parts are similar in geologic structure and climate and which have consequently had a unified geomorphic history.

Physiography: the description and origin of land forms.

Plate Boundary: zone of seismic and tectonic activity along the edges of lithospheric plates presumed to indicate relative motion between plates.

Pliocene: an epoch of the Tertiary period extending from about 5 to 1.6 million years ago.

Plunge: the inclination of a fold axis or other linear structure, measured in the vertical plane.

Porosity: the percentage of the bulk volume of a rock or soil that is occupied by pore spaces (interstices).

Precambrian: all geologic time before the beginning of the Paleozoic era, equivalent to about 90 percent of geologic time.

Precious Metal: a general term for gold, silver, or any of the minerals in the platinum group.

Probability Analysis: an analysis conducted to evaluate the chance that a given event will occur.

Quaternary: a period of the Cenozoic era extending from about 1.6 million years ago to the present.

Radiometric Dating: calculating an age in years for geologic materials by measuring the presence of a short-life radioactive element.

Rangeland: land devoted to the grazing and keeping of animals such as cattle, sheep, and horses.

Reclamation: the process of restoration of an area which has been disturbed.

Relief: the vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region.

Revegetation: regrowth or replacement of a plant community on a disturbed site. Revegetation may be assisted by site preparation, planting, and treatment, or it may occur naturally (secondary succession).

Reverse Fault: opposite of a normal fault, i.e., the overlying side of the fault appears to have moved upward relative to the underlying side of the fault.

Sandstone: a clastic sedimentary rock composed of sand-size particles in a fine-grained matrix and held firmly in place by a cementing material; the consolidated equivalent of sand.

Sediment: solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice.

Sedimentary Rock: a rock resulting from the consolidation of loose sediment that has accumulated in layers.

Seismic: pertaining to an earthquake or earth vibrations including those that are artificially induced.

Seismic Source Zone: a zone determined by tectonics, historic seismicity, or both, which is believed capable of generating earthquakes.

Seismotectonic Province: a region characterized by similar tectonic and seismic characteristics.

Shale: a fine-grained sedimentary rock, formed by the consolidation of clay, silt, and mud.

Siltstone: a fine-grained sedimentary rock, primarily composed of silt-sized particles.

Soil: a natural body consisting of layers or horizons of mineral and/or organic constituents of variable thickness, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties and their biological characteristics.

Soil Profile: a vertical section of a soil that displays all its horizons down to the original rock.

Stratigraphic Column: a composite diagram that shows the subdivisions of part or all of geologic time and the sequence of stratigraphic units of a given locality or region.

Stratigraphic Sequence: a chronologic succession of sedimentary rocks from older below to younger above, essentially without interruption.

Stratigraphic Unit: a stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence for any purpose such as description, mapping, and correlation.

Stratigraphy: the science of rock strata; concerned with the original succession and age relations of rock strata and their individual properties.

Structural Geology: the branch of geology that deals with the form, arrangement, and internal structure of rocks.

Subsidence: the sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion.

Tectonics: a branch of geology that deals with the regional assembling of structural or deformational features, and a study of their mutual relations, origin, and historical evolution.

Terrace: topographic platforms in river valleys that typically represent former levels of the valley floodplain.

Terrace Deposit: the alluvial materials comprising the topographic terrace.

Tertiary: a period of the Cenozoic era extending from about 65 to 1.6 million years ago.

Triassic: a period of the Mesozoic era extending from about 245 to 208 million years ago.

Uplift: a structurally high area in the earth's crust, produced by positive movements that raise or upthrust the rocks, as in a dome or arch.

Valley Fill: unconsolidated sediments deposited by any agent so as to fill or partially fill a valley.

Volcanic Ash: fine-grained material ejected from a volcano.

4.2 Acronyms

ACS	Area of Concentrated Study
AFB	Air Force Base
BLM	Bureau of Land Management
DA	Deployment Area
DAR	Defense Access Road
DOE	Department of Energy
EIS	Environmental Impact Statement
EPTR	Environmental Planning Technical Report
FEIS	Final Environmental Impact Statement
M-X	Missile Experimental
NEIS	National Earthquake Information Service
NOAA	National Oceanographic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
ROI	Region of Influence
SCS	Soil Conservation Service
USAF	U.S. Air Force
USAFRCE	U.S. Air Force Regional Civil Engineer
USAFRC-BMS	U.S. Air Force Regional Civil Engineer - Ballistic Missile Support
USBM	U.S. Bureau of Mines
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation

4.3 Units of Measurement

cy	cubic yard
ft	foot/feet
ft/mi	feet per mile
lb/acre	pounds per acre
m	magnitude
m_b	body wave magnitudes
mi	mile
M_L	maximum local magnitudes
MMI	Modified Mercalli Intensity
sq ft	square foot (feet)
T/acre/yr	tons per acre per year
T/yr	tons per year

5.0

REFERENCES CITED AND REVIEWED

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Algermissen, S.T., and Perkins, D.M., 1976, "A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States," U.S. Geological Survey, Open File Report 76-416.

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hansen, S.L., and Bender, B.L., 1982, "Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States," U.S. Geological Survey, Open File Report 82-1033.

Allen, C.R., 1975, "Geological Criteria for Evaluating Seismicity," Geological Society of America Bulletin, Vol. 86.

Anderman, George G. and Ackman, Edward J., 1963, "Structure of the Denver-Julesburg Basin and Surrounding Areas," Guidebook to the Geology of the Northern Denver Basin and Adjacent Uplifts, Bolyard and Katich, editors, Rocky Mountain Association of Geologists.

Babcock, H.M. and Bjorklund, L.J., 1956, "Groundwater Geology of Part of Laramie and Albany Counties Wyoming, and Weld County, Colorado," U.S. Geological Survey, Water Supply Paper 1367.

Bard, C.S., 1982, "Delineation of Uranium Exploration Targets in Western Nebraska by Statistical Analysis of Groundwater Geochemistry," National Uranium Resource Evaluation Program, U.S. Department of Energy, Report No. K/UR-48.

Bjorklund, L.J., 1957, "Geology and Groundwater Resources of the Lower Lodgepole Creek Drainage Basin, Nebraska," U.S. Geological Survey, Water Supply Paper 1410.

Bjorklund, L.J., 1959, "Geology and Groundwater Resources of the Upper Lodgepole Creek Drainage Basin, Wyoming," U.S. Geological Survey, Water Supply Paper 1483.

Burchett, R.R., 1979, "Earthquakes in Nebraska," Conservation and Survey Division; Institute of Agricultural and Natural Resources; the University of Nebraska-Lincoln, Education Circular, No. 4.

Burchett, R.R. and Eversoll, D.A., 1982, "Nebraska Mineral Operations Review, 1981," Nebraska Geological Survey, Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Burchett, R.R. and Eversoll, D.A., 1983, "Nebraska Mineral Operations Review, 1982," Nebraska Geological Survey, Conservation and Survey Division, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Clabaugh, S.E., Larrabee, D.M., Griffitts, W.R., Fischer, E.C., and Fox, E.L., 1946, "Construction Materials and Non-metallic Minerals Map of Wyoming," U.S. Geological Survey.

Cluff, L.S., Hanse, W.R., Taylor, C.L., Weaver, K.D., Brogan, G.E., Idriss, I.M., McClure, F.E., and Blayney, J.A., 1972, "Site Evaluation in Seismically Active Regions - An Interdisciplinary Team Approach," Proceedings: International Conference on Microzonation, Vol. 2, pp. 957-987.

Cooley, M.E. and Christ, M.A., 1981, "Generalized Fence Diagram Showing Stratigraphy and Potentiometric Surfaces of the Tertiary Formations in Southeast Wyoming and Adjacent Parts of Colorado," U.S. Geological Survey, Miscellaneous Investigations 1-1308.

Crist, M.A., 1980, "Effect of Pumpage on Groundwater Levels as Modeled in Laramie County, Wyoming," U.S. Geological Survey, Open-File Report 80-1104.

Darton, N.H., 1903, "Preliminary Report on the Geology and Water Resources of Nebraska West of the One Hundred and Third Meridian," U.S. Geological Survey, Professional Paper No. 17.

DeGraw, Harold, M., 1969, "Subsurface Relations of the Cretaceous and Tertiary in Western Nebraska," M.S. Thesis, University of Nebraska.

Denson, N.M. and Botinelly, Theodore, 1949, "Geology of the Hartville Uplift, Eastern Wyoming," U.S. Geological Survey, Oil and Gas Investigation Preliminary Map 102.

Docekal, Jerry, 1970, "Earthquakes of the Stable Interior with Emphasis on the Midcontinent," Ph.D. dissertation, University of Nebraska, pp. 332.

Droullard, E.K., 1963 "Tectonics of the Southwest Flank of the Hartville Uplift, Wyoming," Guidebook to the Geology of the Northern Denver Basin and Adjacent Uplifts, Bolyard and Katich, editors, Rocky Mountain Association of Geologists.

Elder, J.A., 1969, "Soils of Nebraska," University of Nebraska, Conservation and Survey Division, Resource Report No. 2.

Earth Technology Corporation 1983, Personal communication with Project Manager for Peacekeeper in Minuteman Silos project.

Evans, D.M., 1966, "The Denver Area Earthquakes and the Rocky Mountain Arsenal Disposal Well," The Mountain Geologist, Vol. 3, No. 1, pp. 23-26.

Geometrics, 1978, "Aerial Gamma Ray and Magnetic Survey, Rockies-Laramie Range Project," NURE Program of the Department of Energy, Open File Report GJBX-17(79).

Glass, G.B., 1978, "Wyoming Coal Fields, 1978," Public Information Circular No. 9, Geological Survey of Wyoming.

Gottula, J.J., 1980, "Groundwater Levels in Pumpkin Creek Valley, Western Nebraska," University of Nebraska, Nebraska Water Survey Open-File Report.

Griffin, J.R. and Warner, A.J., 1981, "Uranium Resource Evaluation, Cheyenne Quadrangle, Wyoming, Colorado, Nebraska," NURE Program of the Department of Energy, Bendix Field Engineering Company, Open File Report PGJ-115(81).

Hausel, W.D., Glass, G.B., Lageson, D.R., Ver Ploeg, A.J., and DeBruin, R.H., 1979, "Wyoming Mines and Minerals," Geological Survey of Wyoming Map.

Hayes, F.A. and Bedell, H.L., 1921, "Soil Survey of Banner County, Nebraska," U.S. Department of Agriculture, Bureau of Soils.

Kirkham, R.M. and Ladwig, L.R., 1980, "Energy Resources of the Denver and Cheyenne Basins, Colorado," Colorado Geological Survey, Environmental Geology 12.

Krinitzsky, E.L. and Chang F.K., 1977, "Specifying Peak Motions for Design Earthquakes," Report of U.S. Army Corps of Engineers, Miscellaneous paper S-73-1 series, State of the Art for Assessing Earthquake Hazards in the United States.

Libra, R.D., Collentine, Michael, and Feathers, K.R., 1981, "Occurrence and Characteristics of Groundwater in the Denver-Julesburg Basin, Wyoming," Report to U.S. Environmental Protection Agency by the Water Resources Research Institute, University of Wyoming.

Lowry, M.E. and Crist, M.A., 1967, "Geology and Groundwater Resources of Laramie County, Wyoming," U.S. Geological Survey, Water Supply Paper 1834.

Liu, S.C. and De Capua, N.J., 1975, "Microzonation of the Rocky Mountain States," Proceedings of the U.S. National Conference on Earthquake Engineering - 1975, Ann Arbor, Michigan, pp. 128-135.

McCoy, A.W., III, 1953, "Tectonic History of the Denver Basin," American Association of Petroleum Geologists, Bulletin, Vol. 37, No. 8, pp. 1873-1893.

McGarr, A., 1982, "Analysis of States of Stress Between Provinces of Constant Stress," preprint submitted to the American Geophysical Union Journal of Geophysical Research.

McGinnis, C.J., 1958, "Habitat of Oil in the Denver Basin," in Habitat of Oil-A Symposium, Weeks, Editor, pp. 328-343.

McGrew, L.W., 1955, "Map of Wyoming Showing Test Wells for Oil and Gas, Anticlines, Oil and Gas Fields and Pipelines," U.S. Geological Survey, Oil and Gas Investigation Map OM-175.

McGrew, L.W., 1962, "Quaternary Faulting in Southeastern Wyoming," unpublished work done in cooperation with the Geological Survey of Wyoming and the Department of Geology, University of Wyoming.

Morris, Donald A. and Babcock, Horace M., 1960, "Geology and Groundwater Resources of Platte County, Wyoming," U.S. Geological Survey, Water Supply Paper 1490.

Murray, H.F., 1957, "Stratigraphic Traps in the Denver Basin," AAPG Bulletin 41, Vol. 5, pp. 839-847.

National Earthquake Information Service (NEIS), 1982, "Worldwide Earthquake Data Tape through May 1981," Boulder, Colorado.

National Earthquake Information Service (NEIS), 1983, "Recent Earthquakes in Colorado, Nebraska, and Wyoming (1979 - August 1983)," Denver, Colorado.

National Oceanic and Atmospheric Administration (NOAA), 1977, "Geothermal Energy Resources of the Western United States," Department of Commerce, Boulder, Colorado.

National Oceanic and Atmospheric Administration (NOAA), 1982, "Geothermal Resources of Nebraska," prepared for the Division of Geothermal Energy, U.S. Department of Energy.

Nebraska Department of Roads, 1983, unpublished data files on aggregate resources.

Nebraska Oil and Gas Conservation Commission, 1983, unpublished data files on oil and gas resources.

Nielson, G.F. (Editor), 1980, "1980 Keystone Coal Industry Manual," McGraw-Hill, New York, New York.

Nuclear Regulatory Commission (NRC), 1975, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," Title 10, Chap. 1, Code of Federal Regulations.

Osterwald, F.W., Osterwald, D.B., Long, J.S., and Wilson, W.H., 1959, "Mineral Resources of Wyoming," Geological Survey of Wyoming, Bulletin No. 50.

Petroleum Information Corporation, 1982, "Well Completion Report Cards," 53 Wells in Laramie County, Wyoming and Denver, Colorado.

Petroleum Information Corporation, 1983a, "Southeast Wyoming Basin Map," posted to 27 October 1983.

Petroleum Information Corporation, 1983b, "Western Nebraska Basin Map," posted to 27 October 1983.

Petroleum Information Corporation, 1983c, "Northeast Colorado Basin Map," posted to 27 October 1983.

POMCO, 1978, "Wyoming Structure Contour Map," Petroleum Information Corp, Casper, Wyoming.

POMCO, 1980, "Structure Contour Map of Denver Basin, Wyoming and Colorado," compiled by Barlow and Haun, Inc., Casper, Wyoming.

Raisz, Erwin, 1957, "Landforms of the United States," A map to accompany Atwood's "Physiographic Provinces of North America," Sixth Revised Edition.

Raleigh, C.B., Healy, J.H., and Bredehoeft, J.D., 1976, "An Experiment in Earthquake Control at Rangley, Colorado," Science, Vol. 1919, pp. 1230-1237.

Rapp, J.R., Vishner, F.N., and Littleton, R.T., 1957, "Geology and Groundwater Resources of Goshen County, Wyoming," U.S. Geological Survey, Water Supply Paper 1377.

Rapp, J.R., Warner, D.A., and Morgan, A.M., 1953, "Geology and Groundwater Resources of the Egbert-Pine Bluffs-Carpenter Area, Laramie County, Wyoming," U.S. Geological Survey, Water Supply Paper 1140.

Reagor, B.R., Stover, C.W. and Algermissen, S.T., 1981, "Seismicity of Nebraska," U.S. Geological Survey, Map MF-1350.

Reed, M.J. and Sorey, M.A., 1981, "Low-Temperature Geothermal Resource Assessment of the United States," Geothermal Resource Council Bulletin, Vol. 10, No. 6, pp. 11-14.

Richter, C.F., 1958, "Elementary Seismology," W.H. Freeman and Co., San Francisco and London.

Schwochow, S.D., Shroba, R.R., and Wicklein, P.C., 1974a, "Sand, Gravel, and Quarry Aggregate Resources, Colorado Front Range Counties," Colorado Geological Survey, Special Publication 5-A.

Schwochow, S.D., Shroba, R.R., and Wicklein, P.C., 1974b, "Atlas of Sand, Gravel, and Quarry Aggregate Resources, Colorado Front Ranges," Colorado Geological Survey, Special Publication 5-B.

Simon, R.B., 1972, "Seismicity," Geologic Atlas of the Rocky Mountain Region, W.W. Mallory, ed., Rocky Mountain Association of Geologists.

Slemmons, D.B., and McKinney, R., 1977, "Definition of Active Fault," U.S. Army Corps of Engineers, Misc. Paper S-77-8.

Smith, R.O., Schneider, Paul A. Jr, and Petri, L.J., 1964, "Groundwater Resources of the South Platte River System in Western Adams and Southwestern Weld Counties," U.S. Geological Survey, Water Supply Paper 1658.

Smith, Frank A. and Souders, Vernon L., 1975, "Groundwater Geology of Banner County, Nebraska," Nebraska Water Survey Paper, Number 39.

Soil Conservation Service (SCS), 1968, "Soil Survey, Scotts Bluff County, Nebraska," U.S. Department of Agriculture.

Soil Conservation Service (SCS), 1971, "Soil Survey, Goshen County, Wyoming, Southern Part," U.S. Department of Agriculture.

Soil Conservation Service (SCS), 1975a, "Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys," U.S. Department of Agriculture, Handbook 436.

Soil Conservation Service (SCS), 1975b, "Procedure for Computing Sheet and Rill Erosion on Project Areas," U.S. Department of Agriculture, Technical Release No. 51.

Soil Conservation Service (SCS), 1982a, "Wind Erosion Equation, Technical Notes, Resource Conservation Planning - WY-2," U.S. Department of Agriculture.

Soil Conservation Service (SCS), 1982b, "Soil Survey, Eastern Part of Laramie County, Wyoming (Draft)," U.S. Department of Agriculture, Cheyenne, Wyoming.

Soil Conservation Service (SCS), 1982c (revised), "Technical Range Site Descriptions, Technical Guide, Section 2E," Casper, Wyoming.

Soil Conservation Service and Conservation and Survey Division, 1982, "General Soil Map of Scottsbluff Area, Nebraska," Institute of Agriculture and Natural Resources, University of Nebraska - Lincoln.

Sonnenberg, Stephen A. and Weimer, Robert J., 1981, "Tectonics, Sedimentation, and Petroleum Potential, Northern Denver Basin, Colorado, Wyoming, and Nebraska," Colorado School of Mines, Quarterly, Vol. 76, No. 2.

Trexler, D.K., 1978, "Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Cheyenne NTMS Quadrangle, Wyoming," NURE Program of the Department of Energy, Open File Report GJBX 106(78).

Union Carbide Corporation, 1980, "Uranium Hydrogeochemical and Stream Sediment Reconnaissance Detail Area, Laramie Range," NURE Program of the Department of Energy, Open File Report 100(80).

University of Nebraska, 1983, Personal communication with Research Associate.

University of Wyoming, Agricultural Experimental Station, 1977, "General Soil Map of Wyoming," Research Journal 117, Laramie, Wyoming.

USAF, 1975, F.E. Warren AFB, "Master Plan, Base Plan Prime - Unique Land & Flood Plain Map," 3 sheets.

USAFRCE-BMS, USAF, 1983a, "Energy and Mineral Resources Map," with technical report, prepared by the Earth Technology Corporation.

USAFRCE-BMS, USAF, 1983b, "Geologic Resources Environmental Planning Technical Report - Closely Spaced Basing," Norton AFB, California.

USAFRCE-BMS, USAF, 1983c, "Regional Aggregate Resources Evaluation, F.E. Warren Candidate Suitable Area Wyoming," prepared by Earth Technology Corporation.

USAFRCE-BMS, USAF, 1983d, "Preliminary Field Investigation Report, MX Closely Spaced Basing, F.E. Warren PCSA, Wyoming," prepared by Earth Technology Corporation.

USAFRCE, USAF, 1983E, "Working Paper Draft on the Potential for Earthquakes and Surface Faulting on the Wheatland-Whalen Fault System, Southeastern Wyoming," prepared by the Earth Technology Corporation.

U.S. Army, Corps of Engineers, 1983a, written communication.

U.S. Army, Corps of Engineers, 1983b, Construction Materials Survey (Phase II), Peacekeeper Facilities, Cheyenne, Wyoming area.

U.S. Bureau of Reclamation (USBR) 1983, "Seismotectonic Study Guernsey Dam North Platte Project, Wyoming," Seismotectonic Report 83-4.

U.S. Geological Survey (USGS), 1964, "Reported Occurrences of Selected Minerals in Wyoming," U.S. Geological Survey, Mineral Investigation Resource Map MR-42.

U.S. Geological Survey (USGS), 1980, "Principles of a Resource Reserve Classification for Minerals," Circular 831, Washington, DC.

U.S. Geological Survey (USGS), 1982, "Land Use, Land Cover Map, Laramie County, Wyoming," Denver, Colorado.

U.S. Geological Survey (USGS) and Colorado Geological Survey, 1977, "Energy Resources Map of Colorado," U.S. Geological Survey, Miscellaneous Investigations Map 1-1039.

Ver Ploeg, A.J., DeBruin, R.H., and Lagesoin, D.R., 1980, "Oil and Gas Map of Wyoming," Geological Survey of Wyoming, Map Series 6.

Warner, Lawrence A., 1978, "The Colorado Lineament: A Middle Precambrian Wrench Fault System," Geological Society of America Bulletin, Vol. 89, pp. 161-171.

Weeks, Edwin P., 1964, "Hydrologic Conditions in the Wheatland Flats Area, Platte County, Wyoming," U.S. Geological Survey, Water Supply Paper 1783.

Wenzel, L.K., Cady, R.C., and Waite, H.A., 1946, "Geology and Ground Water Resources of Scotts Bluff County, Nebraska," U.S. Geological Survey, Water Supply Paper 943.

Woodruff, N.P. and Siddoway, F.H., 1965, "A Wind Erosion Equation," Soil Science Society of America Proceedings, Vol. 29, pp. 602-608.

Wyoming Oil and Gas Conservation Commission, 1981, "Wyoming Oil and Gas Statistics, 1981," Casper, Wyoming.

Wyoming Highway Department, 1983, Unpublished data files on aggregate resources.

Zoback, M.L. and Zoback, M., 1980, "State of Stress in the Conterminous United States," Journal of Geophysical Research, Vol. 85, pp. 6113-6156.

6.0

LIST OF PREPARERS

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David P. Findley, Project Engineering Geologist, Golder Associates
A.S., 1972, West Valley College, Saratoga, California
B.A., 1976, Geology, Humboldt State University, Arcata, California
M.S., 1983, Engineering Geology, Mackay School of Mines, University of Nevada, Reno
Years of Experience: 6

Hugh M. Gauntt, P.E., Geotechnical Engineer, Associate - Golder Associates
B.S., 1974, Agricultural Engineering, University of Georgia, Athens
M.S., 1979, Geotechnical Engineering, Georgia Institute of Technology, Atlanta
Years of Experience: 8

Renner Hoffman, Geophysicist, Golder Associates
B.A., 1952, Geology, University of Wichita, Kansas
M.S., 1955, Geophysics, St. Louis University, Missouri
Years of Experience: 28

Richard J. Kramer, E.P., NAEP, Natural Resources Director, URS-Berger
B.A., 1960, Biology, St. John's University, Collegeville, Minnesota
M.S., 1962, Plant Ecology, Arizona State University, Tempe
Ph.D., 1968, Plant Ecology and the Physical Environment, Rutgers University, New Brunswick, New Jersey
Years of Experience: 23

W. Tony Morgan, Geologist, URS-Berger
B.S., 1979, Geology, Indiana University, Indianapolis
M.A., 1983, Geology, Indiana University, Bloomington
Years of Experience: 4

Charles (Rus) Purcell, Geologic Resources Manager, URS-Berger
B.S., 1971, Geology, University of Cincinnati, Ohio
M.S., 1973, Geology, University of Cincinnati, Ohio
Years of Experience: 12

Kenneth H. Rippere, P.G., Principal Geological Engineer, Golder Associates
Geological Engineer, 1966, Colorado School of Mines, Golden, Colorado
Years of Experience: 17

John Scott, Geologist, Associate - Golder Associates
B.A., 1965, Geology, University of California, Los Angeles
Years of Experience: 18

Douglas Tarbett, 2nd Lt., Geologic Resources Module Manager, AFRCE-BMS/DEV
B.S., 1982, Civil Engineering, University of Tennessee, Knoxville
Years of Experience: 1

APPENDIX A

APPENDIX A
SOIL EROSION ASSESSMENT

This appendix describes the basic methodology for using the Wind Erosion Equation (SCS 1982a) and the Universal Soil Loss Equation (USLE) (SCS 1975b). An example problem is solved using each soil loss equation and the applicable tables and figures from the Soil Conservation Service (SCS 1975b, 1982a).

A.1 Procedure for Using the Wind Erosion Equation

The Wind Erosion Equation provides a method for estimating annual soil loss from wind erosion for a particular area. Further details can be obtained from the SCS (1982a) and Sections 2.5.3.1 and 2.6.4.3 of this report.

Wind Erosion Equation

The Wind Erosion Equation (SCS 1982a) states that E, the estimated soil loss in tons per acre per year (T/acre/yr) is a function of I, K, C, L, and V with these variables defined as:

- Baseline Soil Erodibility (I). Factor I is the potential soil erodibility from a wide, unsheltered, isolated field with a bare, smooth surface. Wind erodibility indices are obtained from the Technical Notes on the Wind Erosion Equation (SCS 1982a).

- Baseline Soil Ridge Roughness (K). Factor K is estimated from a standard chart based on the relationship between furrow spacing and depth (SCS 1982a).

- Baseline Climatic Factor (C). The climatic factor C expresses the fact that the ratio of soil flow varies directly as the cube of the wind velocity and inversely as the square of the effective moisture. Soil surface moisture varies directly with the amount of precipitation and inversely as the square of the temperature. The climatic factor is normalized to Garden City, Kansas (C = 100). In all other areas of the United States, the C factor is expressed as a percentage of the Garden City value. Wind erosion conditions are also affected by the magnitude of the wind erosive forces, the direction of the prevailing wind, and the preponderance of erosive forces in the direction of the prevailing erosive wind (SCS 1982a).

- Baseline Affected Length (L). This factor is the unsheltered distance across a strip parallel to the direction of the prevailing erosive wind. The distance depends on the deviation of the wind's erosive force from a right angle with respect to the field width or strip.

- Baseline Vegetative Cover (V). Good vegetative cover on the land surface is the most effective way to control wind erosion. Living or dead vegetative matter protects the soil surface from wind action by reducing wind speed and preventing the direct force of the wind from reaching erodible soil particles. In addition, vegetative matter reduces the erosion rate by trapping soil particles. Protection of the soil by vegetative matter depends upon three major factors: the kind of vegetation, its quantity, and its orientation. These three factors are expressed as factor V.

Sample Problem

Determine the soil loss for a site with the following conditions:

- o Texture - fine sandy loam;
- o Width of site - 100 feet;
- o Angle of deviation of prevailing wind from perpendicular to field - 45°;
- o Vegetation - wheat (growing) at 400 pounds per acre (lb/acre); and
- o Slope - 5 percent.

Procedure

Step 1: Determine the wind erodibility index (I) for the soil based on the texture (Table A.1-1) The I value for a fine sandy loam is 86.

Step 2: Determine the width of the site (L) along the prevailing wind direction using the alignment chart (Figure A.1-1). The site width along the prevailing wind direction is 150 feet.

Step 3: If the width along the prevailing wind direction is less than 500 feet and the slope is greater than or equal to 3 percent, multiply the I value by a correction factor (Table A.1-2, follows Figure A.1-3). For the given conditions, $I = 86 \cdot 1.9 = 163$.

Step 4: Determine the ridge-roughness factor (K) based on the ridge height and furrow spacing (Figure A.1-2). Assume $K = 0.60$ for this example.

Step 5: Select the correct climatic factor (C) from Figure A.1-3. For areas outside Wyoming, climatic factors may be obtained from local SCS representatives. For eastern Laramie County, $C = 80$.

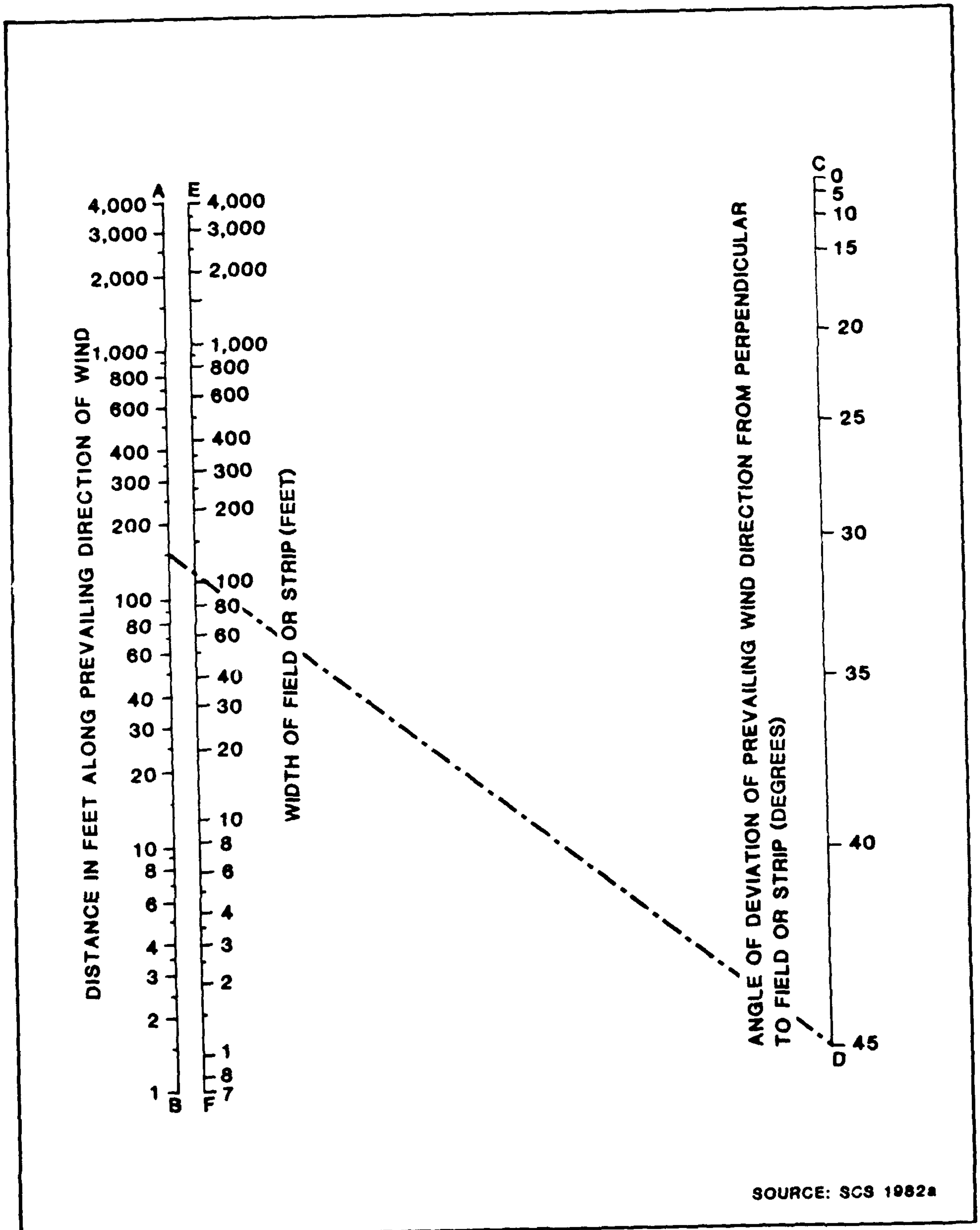
Table A.1-1

WIND ERODIBILITY INDEX

Predominant Soil Texture Class of Surface Layer	Wind Erodibility Index (I) T/acre/yr
Very fine sand, fine sand, sand, or coarse sand	310
Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials (refer to Soil Taxonomy for definition of sapric)[1]	134
Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam	86
Clay, silty clay, noncalcareous clay loam, or silty clay loam with more than 35 percent clay content	86
Calcareous loam and silt loam, or calcareous clay loam and silty clay loam	86
Noncalcareous loam and silt loam with less than 20 percent clay content, or sandy clay loam, sandy clay, and hemic organic soil materials (refer to Soil Taxonomy for definition of hemic)[1]	56
Noncalcareous loam and silt loam with more than 20 percent clay content, or noncalcareous clay loam with less than 35 percent clay content	48
Silt, noncalcareous silty clay loam with less than 35 percent clay content and fibric organic soil material	38
Soils not suitable for cultivation due to coarse fragments or wetness, wind erosion not a problem	—

1 SCS 1975a

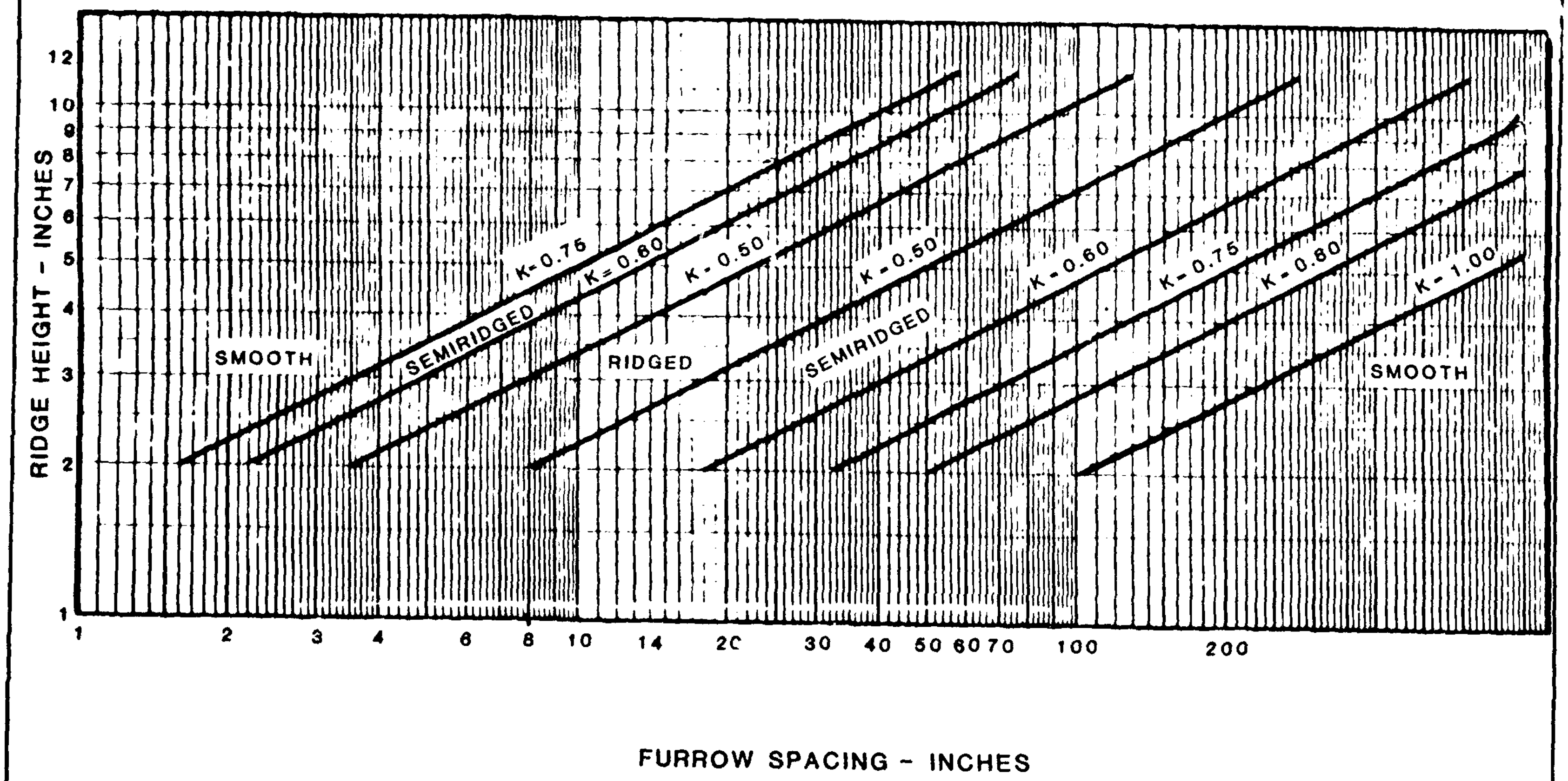
Source: SCS 1982a.



SOURCE: SCS 1982a

ALIGNMENT CHART

FIGURE NO. A.1-1



SOURCE: SCS 1982a

WIND EROSION RIDGE-ROUGHNESS "K" FROM VARIOUS FURROW SPACINGS AND RIDGE HEIGHTS

FIGURE NO. A.1-2

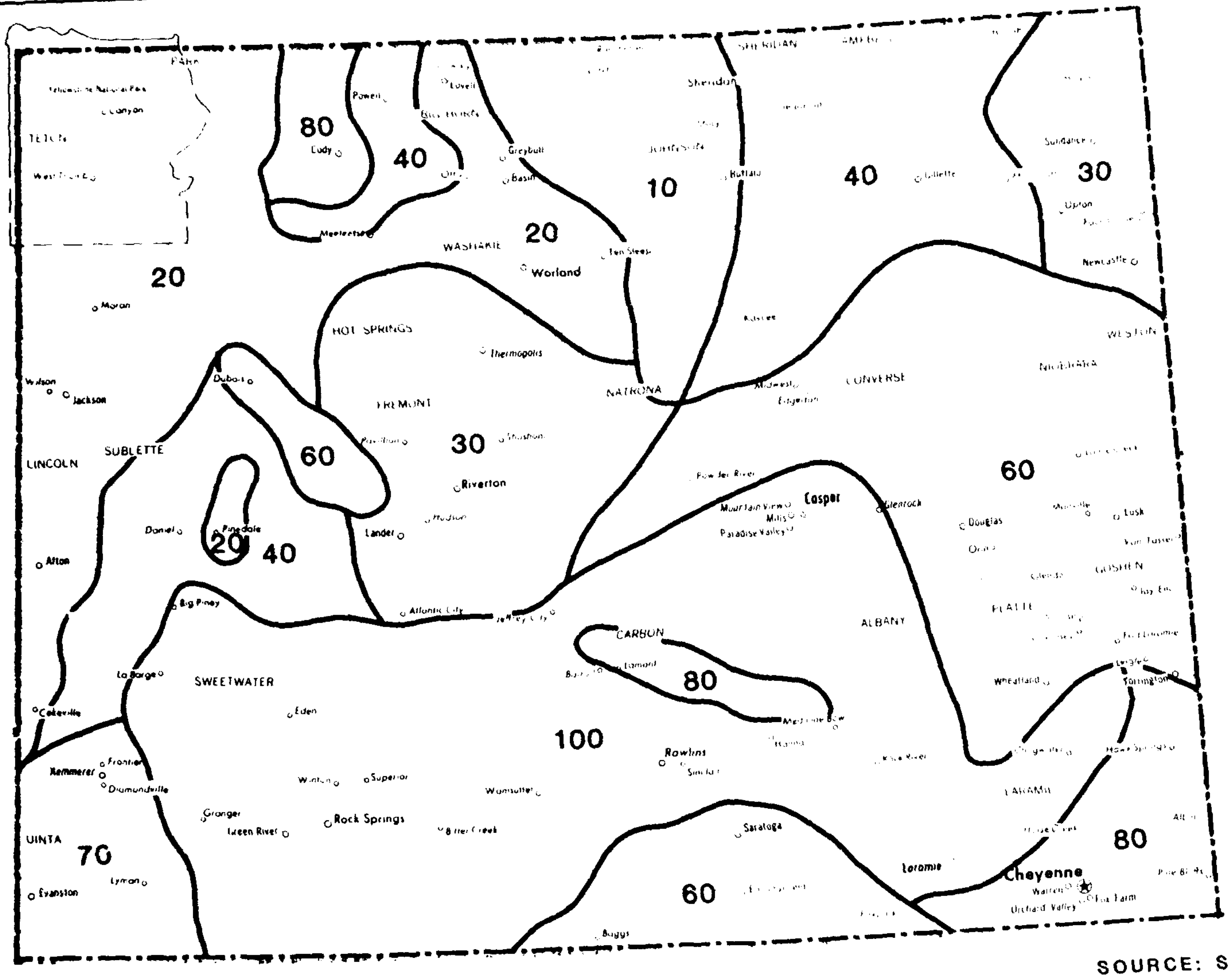


FIGURE NO. A.1-3

WYOMING WIND EROSION CLIMATIC FACTOR C

Table A.1-2

SLOPE CORRECTION FACTORS

Percent Slope	Slope Correction Factor
3	1.3
4	1.6
5	1.9
6	2.3
8	3.0
10	3.6

Source: SCS 1982a.

Step 6: Determine the vegetation residue that will be present during the critical wind erosion period (Figure A.1-4). Wheat growing at 400 lb/acre has a flat, small grain residue equivalent of 800 lb/acre. If the wheat has been combined, use Figure A.1-5. For range vegetation use Table A.1-3.

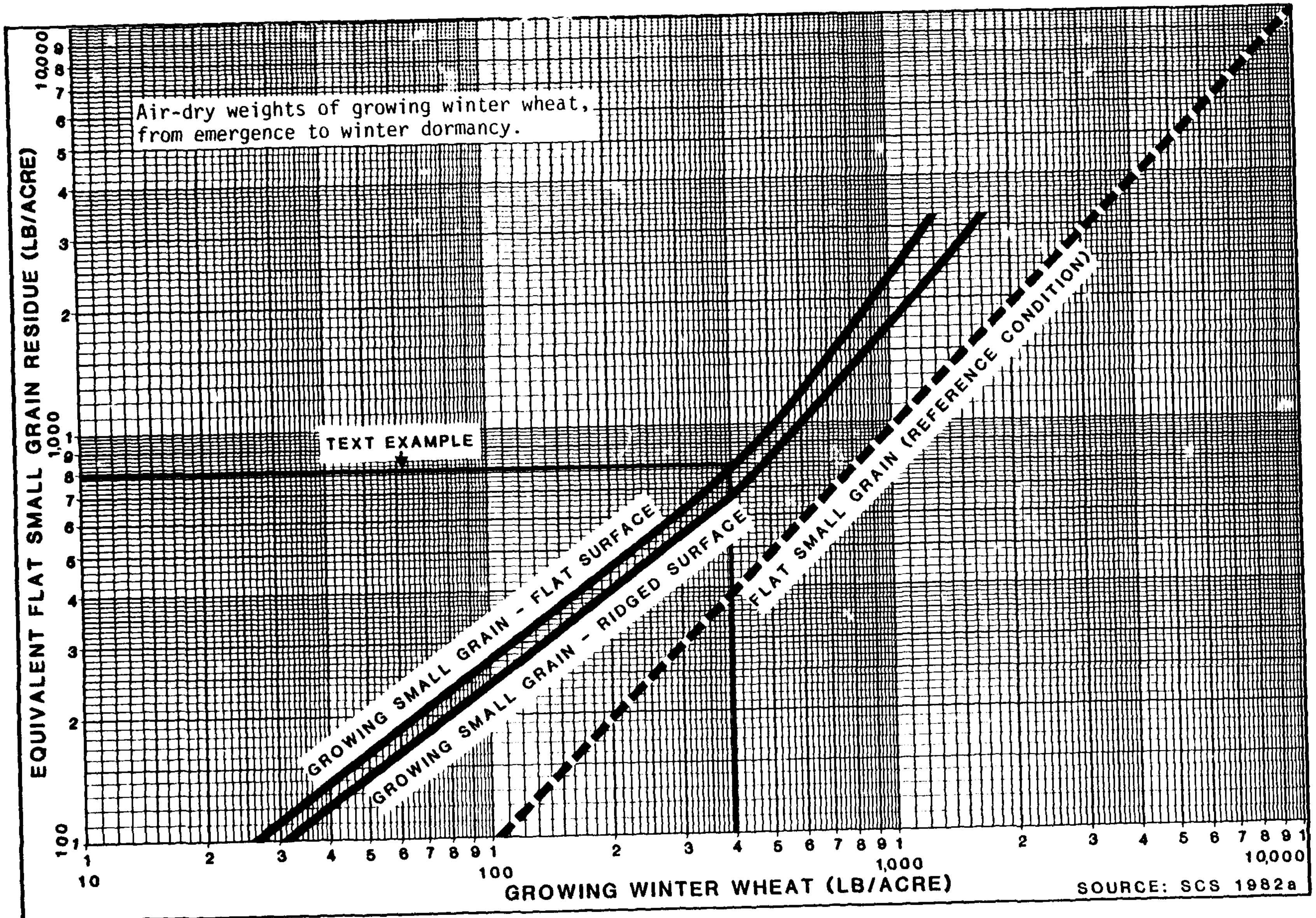
Step 7: Select the correct wind erosion table from SCS (1982a) for the I, C, and K values previously determined. For this example:

I = 163 or approximately 160
C = 80
L = 150 feet
V = 800 lb/acre
K = 0.60

Step 8: Find L = 150 in left-hand column in Table A.1-4. Read across row to column where V = 800. In this case, the V value falls between columns. The estimated soil erosion due to wind is interpolated to be about 16.4 T/acre/yr.

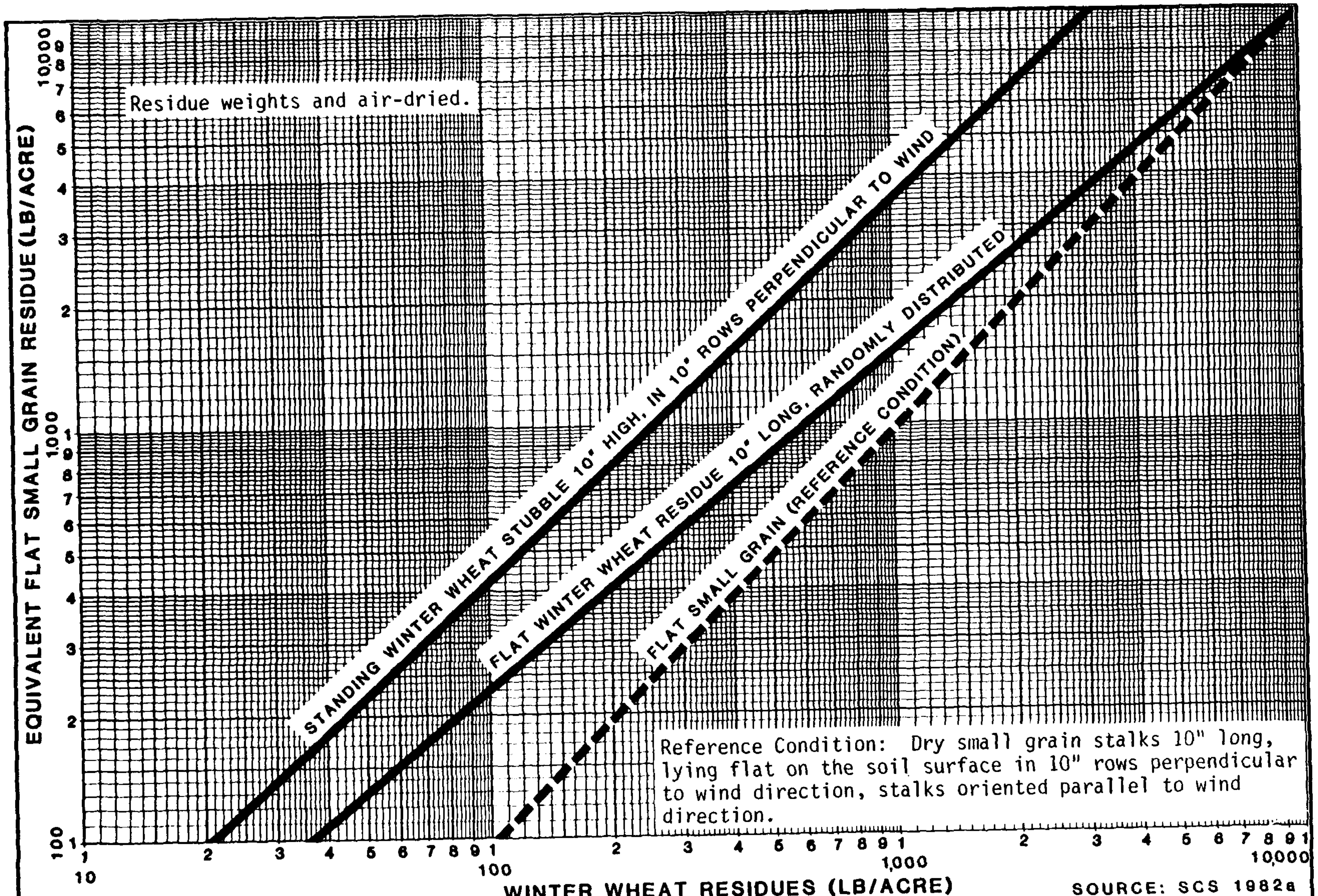
A.2 Procedure for Using the Universal Soil Loss Equation

Computation of erosion by water utilizing the USLE requires multiplication of several input variables. The USLE is $A = R \cdot K \cdot L \cdot S \cdot C \cdot P$ where A is the computed soil loss from sheet and rill erosion in T/acre/yr. The factors are:



FLAT SMALL GRAIN EQUIVALENTS-GROWING WINTER WHEAT

FIGURE NO. A.1-4



FLAT SMALL GRAIN EQUIVALENTS–
WINTER WHEAT RESIDUES

FIGURE NO. A.1-5

Table A.1-3

GUIDE FOR CONVERTING RANGE VEGETATION TO
EQUIVALENT QUANTITY OF FLAT SMALL GRAIN RESIDUE

	Pounds per Acre of Range Vegetation[1]										
	50	100	200	300	400	500	600	700	800	900	1,000
Grass Plants											
*Buffalograss & Inland saltgrass	320	720	1,630	2,630							
*Big bluestem	45	110	280	480	705	950	1,215	1,495	1,785	2,090	2,410
*Western wheatgrass & sideoats grama	155	245	775	1,240	1,740	2,260	2,795	3,345			
*Little bluestem	45	110	285	495	735	995	1,280	1,580	1,900	2,230	2,575
*Blue grama, threadleaf sedge, & perennial threeawns	110	235	490	760	1,040	1,325	1,610	1,905			
Galleta	150	300	800	1,200	1,700	2,600					
Bottlebrush squirreltail * & needleandthread	70	150	300	600	800	1,200					
Alkali sacaton	60	150	400	800	1,400	2,200	2,800	3,600			
Bluebunch wheatgrass	50	120	300	550	850	1,150	1,500	1,900	2,300	2,600	3,000
Idaho fescue	100	200	400	900	1,500	2,300					
Indian ricegrass	100	175	300	600	900	1,400					
Crested wheatgrass	130	300	600	900	1,300	1,800	2,400	3,100	4,000		
Cheatgrass	100	200	300	600	800	1,000	1,200	1,600	2,000	2,500	3,000
Forbs											
Perennial forbs	50	100	300	500							
Annual forbs	50	100	200	300	500	800	1,000				

Table A.1-3 Continued, page 2 of 2
GUIDE FOR CONVERTING RANGE VEGETATION

	Pounds per Acre of Range Vegetation[1]										
	50	100	200	300	400	500	600	700	800	900	1,000
Shrubs											
Big sagebrush	30	70	300	750	1,100	1,500	2,000	2,600	3,200	4,000	
Low sagebrush	50	150	450	900	1,600	2,200	2,900	3,600			
Greasewood and 4-wing saltbush	20	60	250	450	800	1,250	1,800	2,400	3,000		
Rubber and low rabbitbrush	30	70	350	800	1,200	1,700	2,200	2,800	3,400		
Shadscale	30	70	300	500	850	1,300					
Juniper	40	90	180	300	450	800	950	1,300	2,000	2,700	3,600
Yucca[2]	0	70	150	250	400	600	750	1,000	1,400	1,800	
Winterfat	40	100	300	500	800	1,400	1,800	2,300	3,000		
Litter[3]	50	100	200	300	400	500	600	700	800	900	1,000

1 Total leaf and twig growth-air dry weight. Woody production not included in these weight figures.
2 Include all leaf and fibrous material.
3 Litter should include leaves, twigs, and stems up to 1/2 inch in diameter.

* Lyles, Leon and Bruce E. Allison, "Range Grasses and Their Small Grain Equivalents for Wind Erosion Control," Journal of Range Management, Vol. 33, No. 2, March 1980, pp. 143-146.

NOTE: Other grass species equivalents were estimated by comparing the growth characteristics with the tested species.

For deciduous shrubs, estimate foliage production at time of wind erosion hazard.

The forb and shrub small grain equivalents are personal judgment only. No research data is available to report these figures.

Source: SCS 1982a.

Table A.1-4

SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

Surface - K = 0.6

(L) Unsheltered Distance in Feet	(V)** - Flat Small Grain Residue in Pounds per Acre												
	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10,000	76.8	66.9	53.5	40.3	25.5	13.8	7.0	3.6	2.2	0.7			
8,000	76.8	66.9	53.5	40.3	25.5	13.8	7.0	3.6	2.2	0.7			
6,000	76.8	66.9	53.5	40.3	25.5	13.8	7.0	3.6	2.2	0.7			
4,000	76.8	66.9	53.5	40.3	25.5	13.8	7.0	3.6	2.2	0.7			
3,000	76.8	66.9	53.5	40.3	25.5	13.8	7.0	3.6	2.2	0.7			
2,000	75.1	65.4	52.1	39.2	24.7	13.3	6.7	3.4	2.1	0.7			
1,000	69.4	60.2	47.7	35.5	22.1	11.6	5.7	2.8	1.7	0.5			
800	67.0	58.1	45.9	34.0	21.0	10.9	5.3	2.6	1.6	0.5			
600	61.9	53.5	42.0	30.8	18.8	9.5	4.6	2.2	1.3				
400	56.4	48.5	37.8	27.4	16.5	8.1	3.8	1.8	1.0				
300	52.2	44.8	34.7	24.9	14.8	7.1	3.3	1.5	0.8				
200	46.0	39.8	30.1	21.2	12.4	5.7	2.5	1.1	0.5				
150	40.2	34.2	25.9	18.0	10.2	4.5	2.0	0.8	0.4				
100	35.5	30.0	22.5	15.4	8.6	3.7	1.5	0.5					
80	32.8	27.7	20.6	14.0	7.7	3.2	1.3	0.4					
60	27.0	22.6	16.6	10.9	5.8	2.3	0.9						
50	24.1	20.0	14.6	9.9	5.0	1.9	0.7						
40	21.5	18.1	11.1	8.4	4.4	1.6	0.6						
30	18.5	16.2	10.8	6.8	3.4	1.2							
20	13.6	11.1	7.7	4.6	2.2	0.7							
10	7.6	6.1	4.0	2.3	0.9								

Source: SCS 1982a.

- Baseline Rainfall Factor (R). The rainfall factor, R, reflects the energy intensity of rainfall and its total annual effect on erosion of soil particles. R factors for specific sites are calculated from the isoerodent contour plot contained in SCS (1975b).

- Baseline Soil Erodibility Factor (K). The resistance of the soil surface to erosion is a function of its physical and chemical properties. A nomograph is available for calculating the K factors which presents, in graphical form, an equation which considers percent of silt and fine sand, proportion of sand, organic matter content, soil structure index, and permeability (SCS 1975b).

- Baseline Topographic Factor (LS). The erosive capacity of runoff increases rapidly with runoff velocity. Runoff velocity, in turn, depends on flow concentration, length of slope, and steepness. For convenience, these factors are combined into a single topographic factor, LS, which is usually obtained from graphs. Values of LS for slopes with less than a 3-percent gradient and slope lengths greater than 400 feet constitute extrapolations of the formula beyond the range of research data and should be used with caution.

- Baseline Crop Management Factor (C). The basic soil loss is the rate at which the area would erode if it were continuously tilled fallow for which the value of C equals 1.0. The factor C is the percentage of this potential soil loss that would occur if this condition were modified by various types of cover and management strategies.

- Baseline Erosion Control Factor (P). This factor accounts for control practices such as contouring, contour strip-cropping, and contour irrigated fallows that reduce the erosion potential of the runoff. These practices are generally used for soil conservation unless other mitigation measures are adopted. Factor P is assumed to be 1.0 in construction applications of the USLE. Erosion-reducing effects of terraces and diversions are accounted for by modifications to the factor LS.

The factors R, L, and S combine to describe the potential of the erosive agents to detach and transport soil material. Factor K reflects the susceptibility of the soil to detachment and transport. Factors C and P describe the effectiveness of land cover, management techniques, and conservation practices for protecting the soil's surface against the erosive agents.

The SCS (1975) provides a means for estimating factors R, L, S, C, and P. The soil erodibility factor must be calculated or obtained from SCS soil scientists. Further details can be obtained from SCS (1975b) and Sections 2.5.3.2 and 2.6.4.4.

Sample Problem

Determine the average annual soil loss from sheet erosion for the following conditions:

- o Soil - Altvan soil series (K = 0.28);
- o Vegetation - Rangeland with 25 percent canopy cover of tall weeds and 40 percent ground cover;
- o Slope - 8 percent; and
- o Slope length - 200 feet.

Step 1: Determine the rainfall factor (R). For most of the contiguous 48 states, Puerto Rico, and the Virgin Islands, R can be obtained directly from Figure A.2-1. Assume R = 31.0, a value suitable for central Laramie County.

Step 2: Determine the slope length and slope gradient factors. The slope length factor (L) and the slope gradient factor (S) are typically presented as a single topographic factor (LS). The topographic factor for various slope lengths and slope gradients can be obtained directly from Figure A.2-2. For slope lengths and gradients outside the ranges of Figure A.2-2, the topographic factor (LS) can be calculated by the equation at the bottom of Figure A.2-2. The slope length factor is 1.4 for the example.

Step 3: Determine the crop management factor. The crop management factor (C) can be obtained from Table A.2-1. Use of this table requires knowledge of the characteristics of the particular vegetation being grown on the site. The C value for this example is 0.09.

Step 4: Determine the erosion control practice factor. The erosion control practice factor (P) for several erosion control practices can be obtained directly from Table A.2-2. In the event that none of the listed practices are appropriate, the factor P is taken to be 1.0.

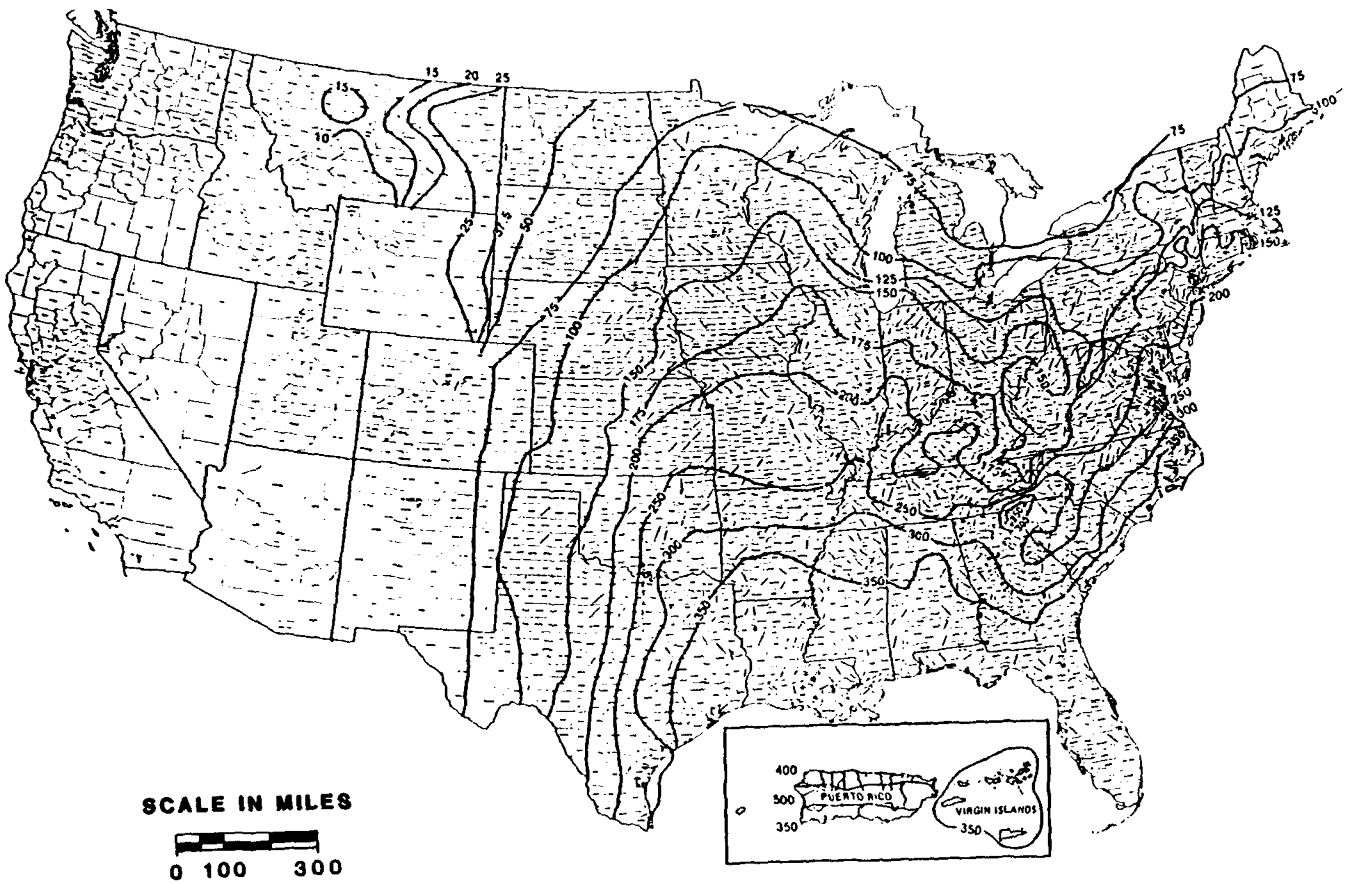
Step 5: Multiplication of the described variables will yield the annual soil loss in T/acre for the particular site being studied.

$$\text{Soil Erosion} = R \cdot K \cdot LS \cdot C \cdot P$$

$$= 31.0 \cdot 0.28 \cdot 1.4 \cdot 0.09 \cdot 1.0$$

Average Annual Soil
Erosion from = 1.1 T/acre/yr
Sheet and Rill Erosion

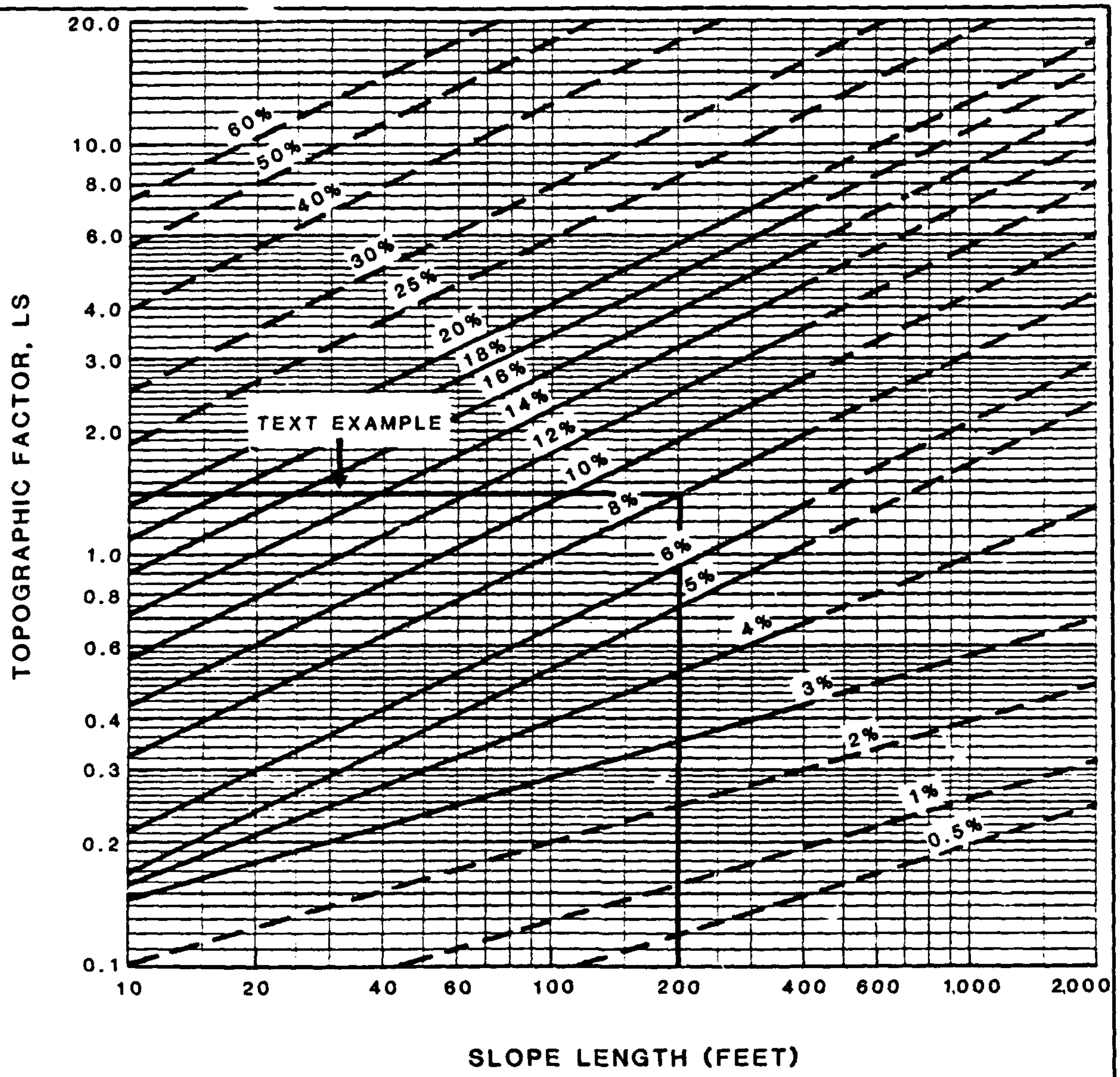
The procedure can be repeated as many times as necessary to adequately predict erosion on project sites with varying conditions.



SOURCE: SCS 1982a

AVERAGE ANNUAL VALUES OF THE
FACTOR R FOR THE UNITED STATES

FIGURE NO. A.2-1



The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available. The curves were derived by the formula:

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 + 30x + 0.43}{6.57415}\right)$$

where λ=field slope length in feet and m=0.5 if s=5% or greater, 0.4 if s=4%, and 0.3 if s=3% or less; and x=sinθ. θ is the angle of slope in degrees.

SOURCE: SCS 1975b

SLOPE-EFFECT CHART (TOPOGRAPHIC FACTOR, LS)

FIGURE NO. A.2-2

Table A.2-1

"C" VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND[1]

Vegetal Canopy		Cover that Contacts the Surface						
Type and Height of Raised Canopy[2]	Canopy Cover[3] %	Type[4]	Percent Ground Cover 0	20	40	60	80	95-100
An appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds or short brush (0.5-m fall height)	25	G	0.36	0.17	0.09	0.038	0.012	0.003
		W	0.36	0.20	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
Appreciable brush or brushes (2 m fall height)	25	G	0.40	0.18	0.09	0.040	0.013	0.003
		W	0.40	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.085	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.040	0.011
Trees but no appreciable low brush (4 m fall height)	25	G	0.42	0.19	0.10	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

1 All values shown assume: 1) random distribution of mulch or vegetation, and 2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of 3 consecutive years.

2 Average fall height of waterdrops from canopy to soil surface: m = meters.

3 Portion of total area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

4 G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) and/or undecayed residue.

Source: SCS 1975b.

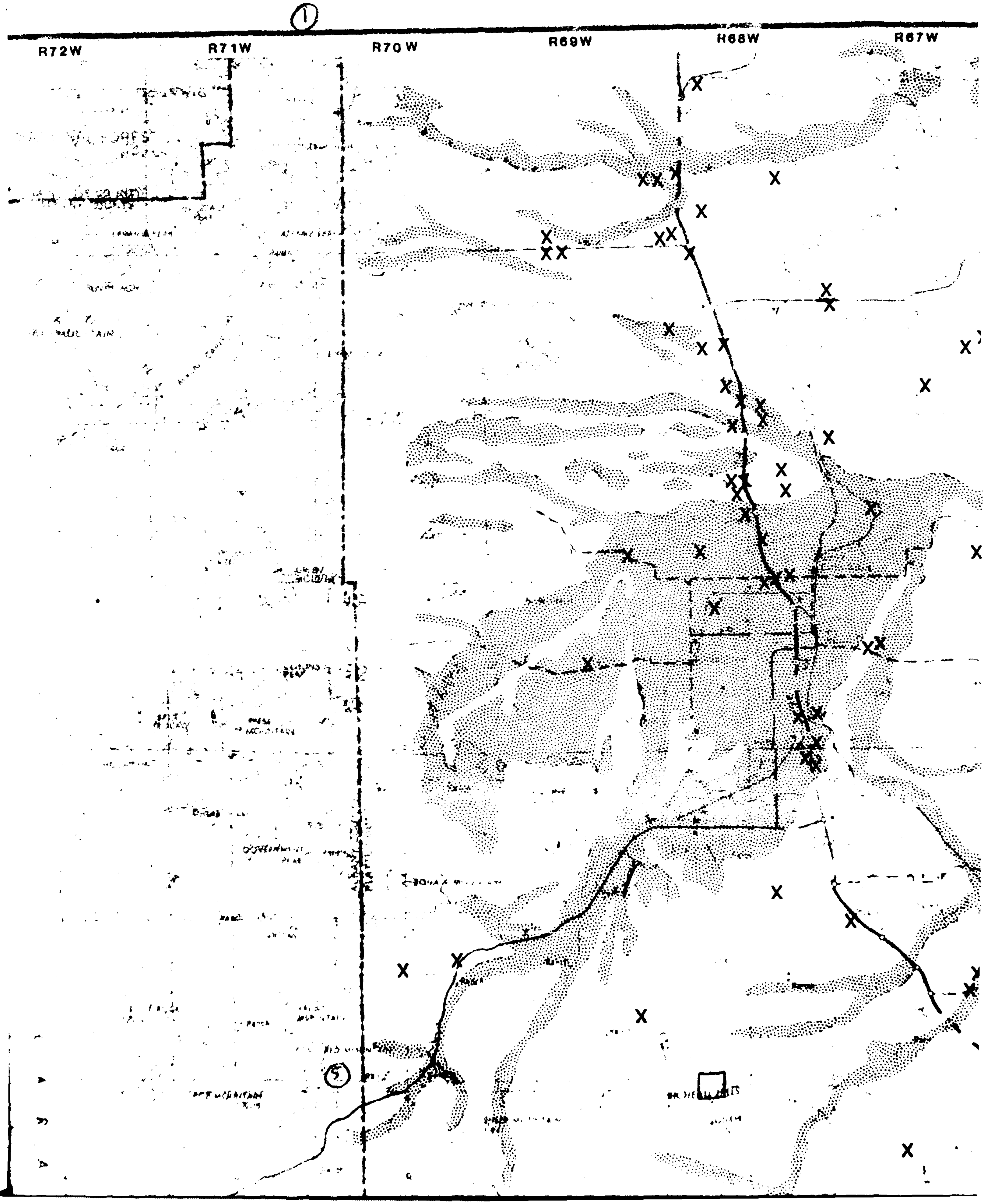
Table A.2-2

EROSION CONTROL PRACTICE FACTOR (P)

	P Values			
Land Slope Percentage	Contouring	Contour Strip-cropping	Contour Irrigated Furrows	Terracing[1]
2.0 - 7	0.50	0.25	0.25	0.10
8.0 - 12	0.60	0.30	0.30	0.12
13.0 - 18	0.80	0.40	0.40	0.16
19.0 - 24	0.90	0.45	0.45	0.18

1 For prediction of contribution to off-field sediment load

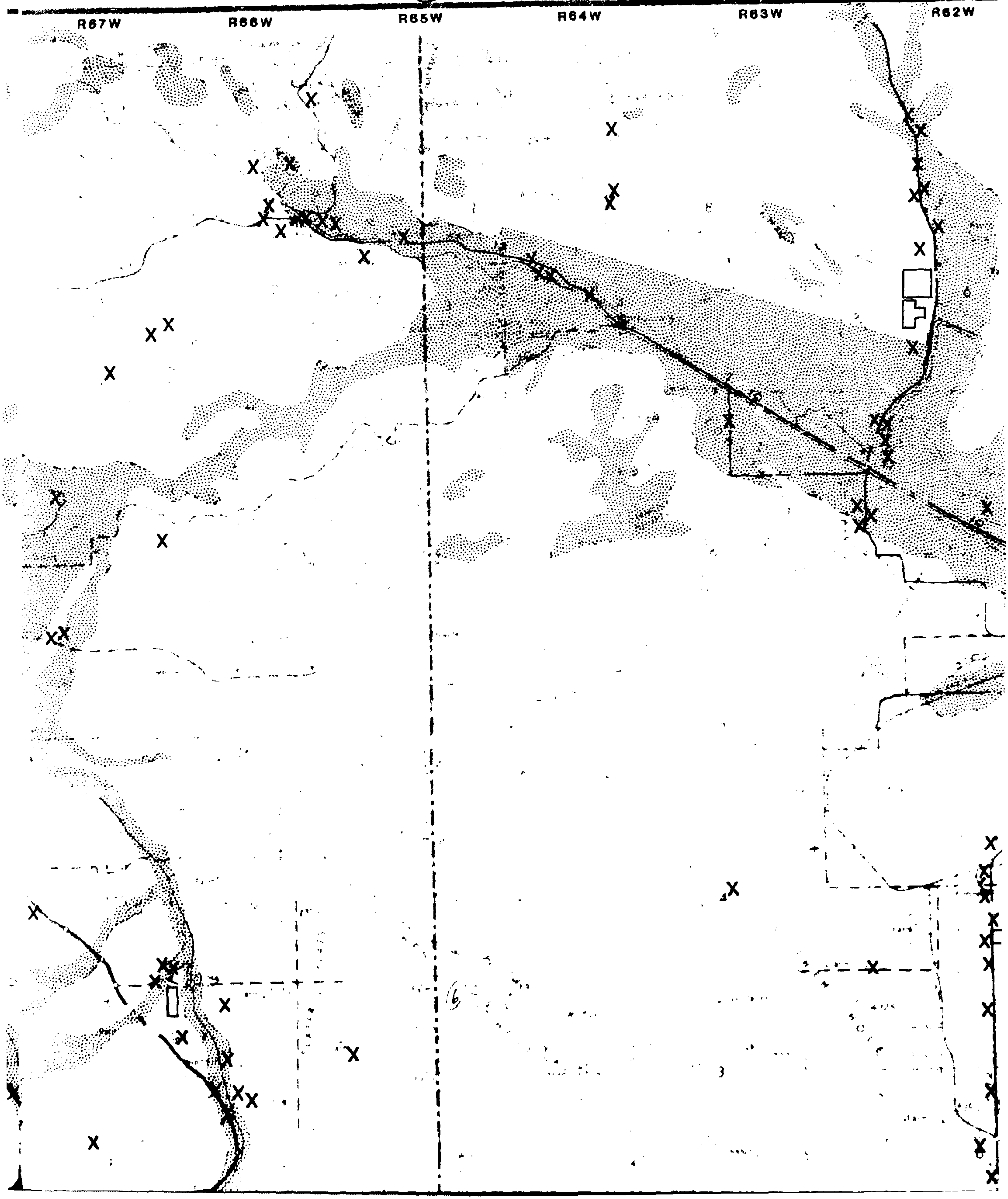
Source: SCS 1975b.

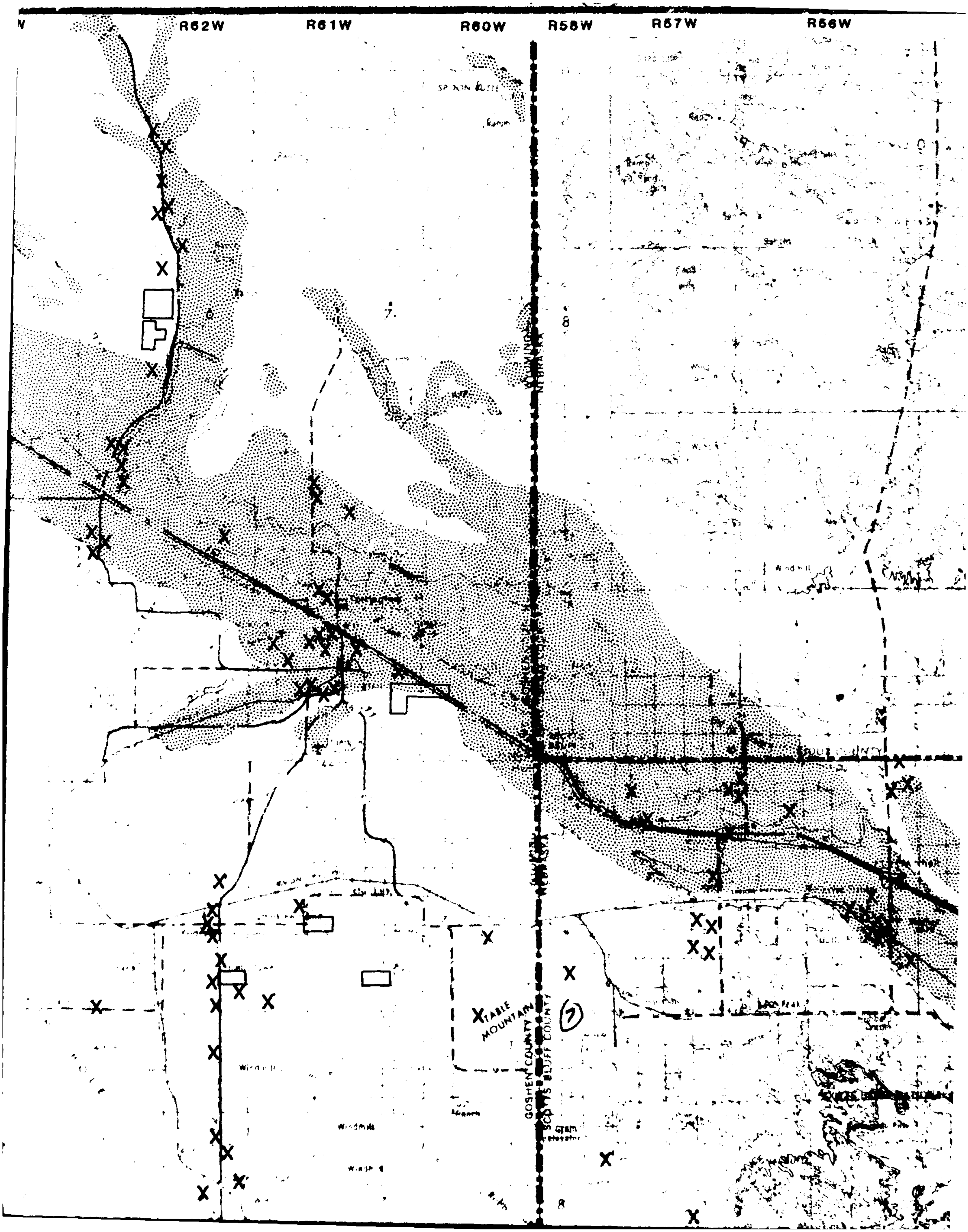


1
R72W
R71W
R70W
R69W
R68W
R67W
5

1

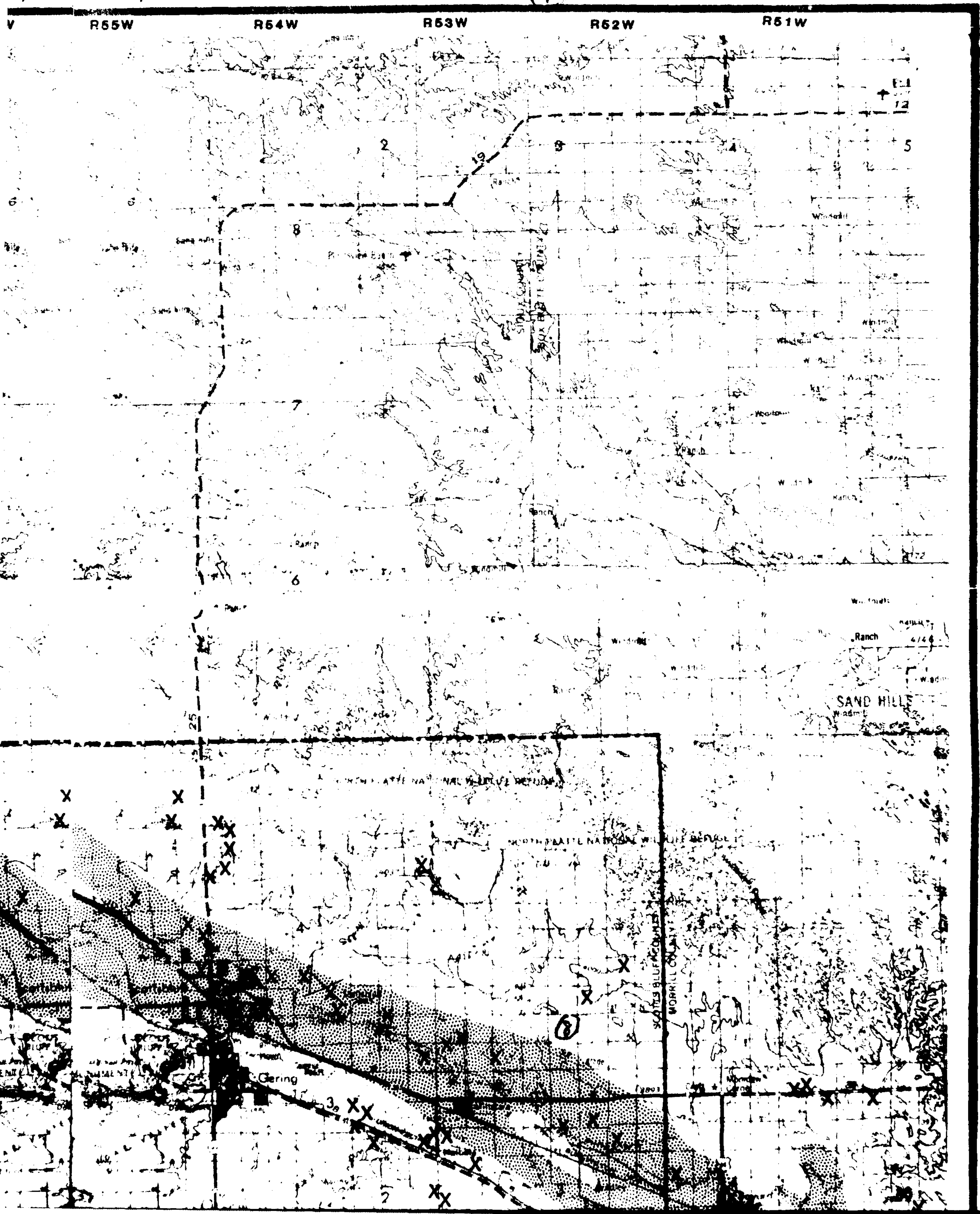
(2)

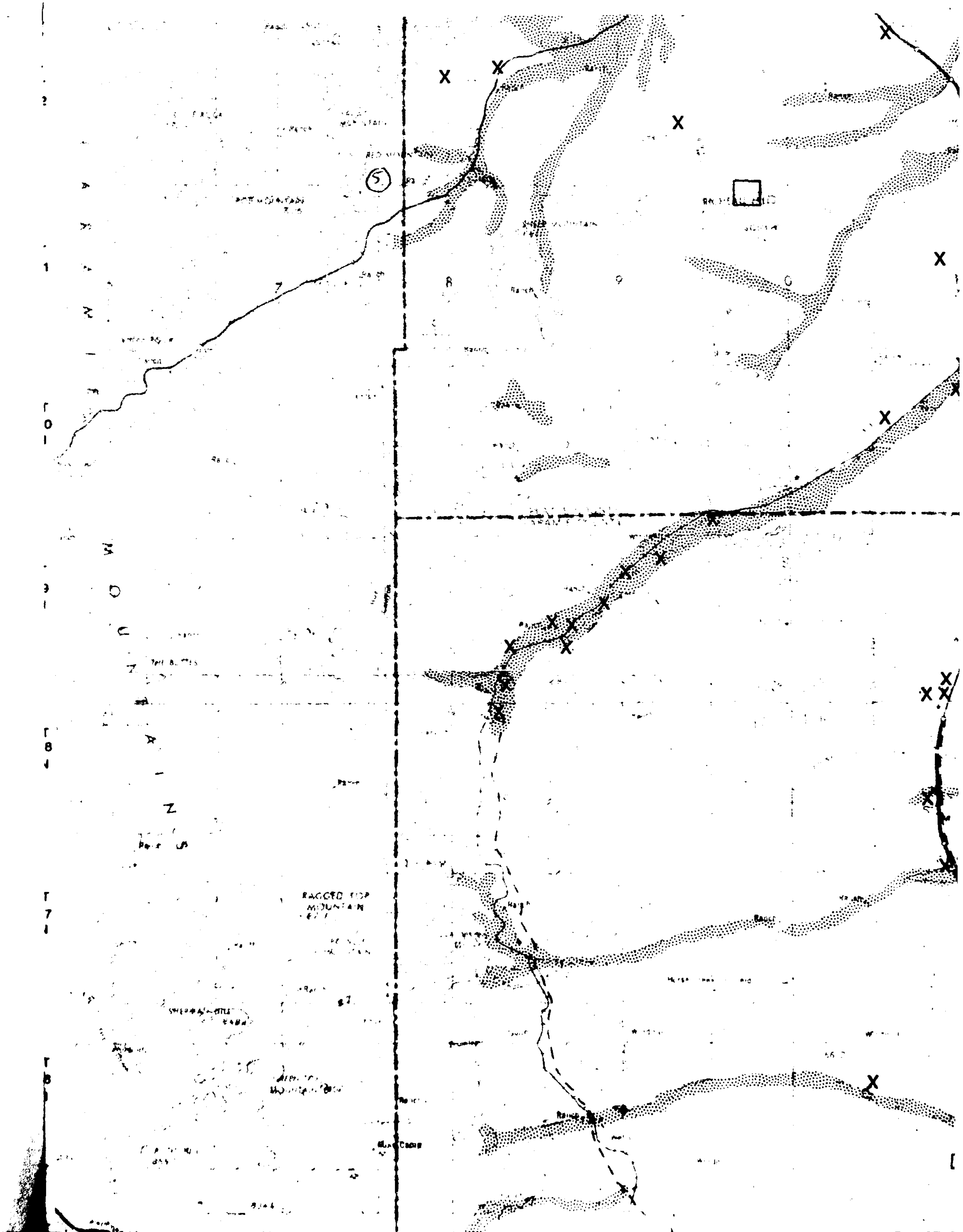


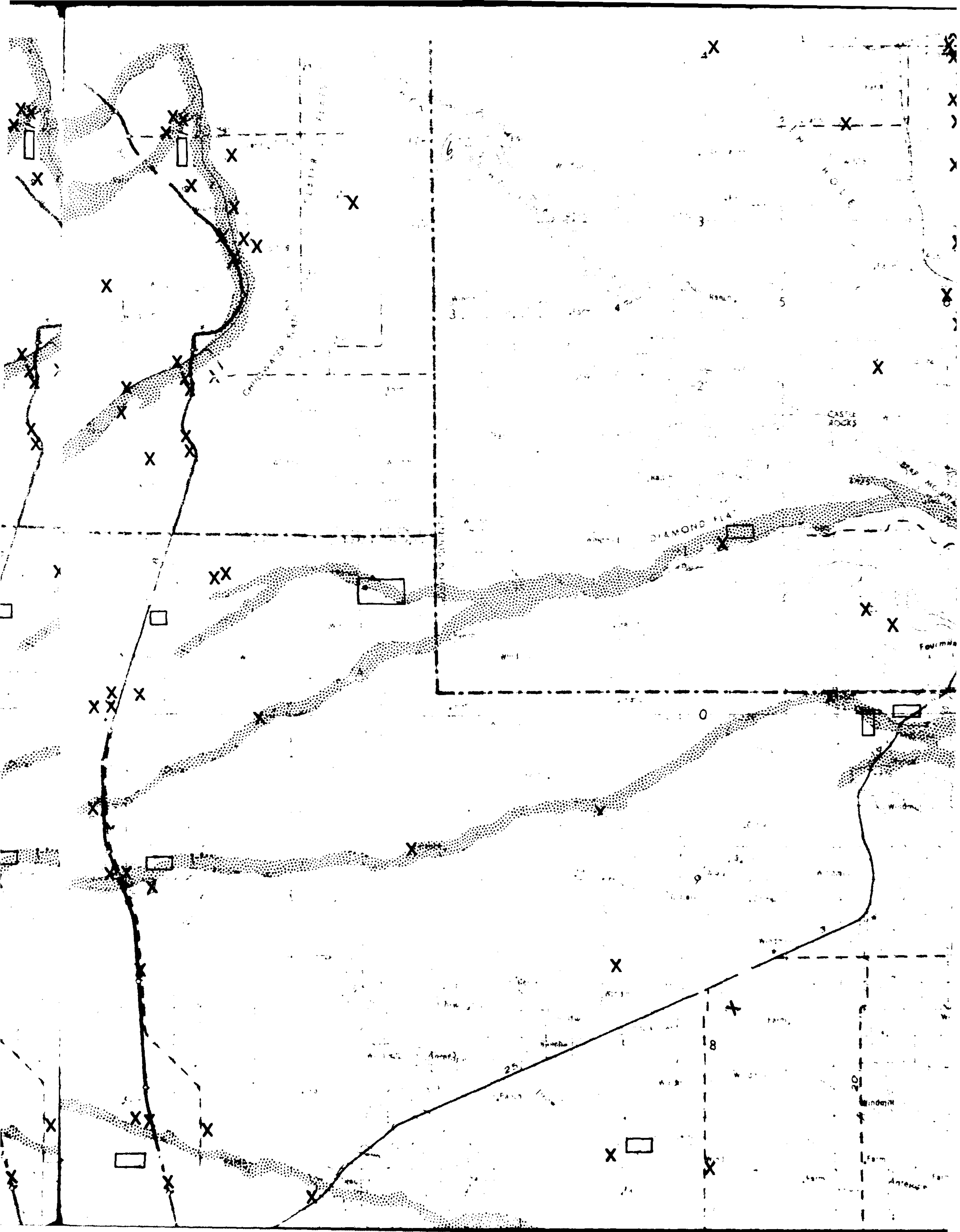


R62W
R61W
R60W
R58W
R57W
R56W
WYOMING
NEBRASKA
GOSHEN COUNTY
SCOTTS BLUFF COUNTY
TABLE MOUNTAIN
SIOUX COUNTY
Windmill

(4)


R55W
R54W
R53W
R52W
R51W
SIOUX COUNTY
BOX BUTTE COUNTY
SAND HILLS
NORTH PLATTE NATIONAL WILDLIFE REFUGE
SCOTTS BLUFF COUNTY
MORRILL COUNTY
Gering
Ranch
Windmill


RAGGED TOP
MOUNTAIN


DIAMOND FLAT
CASTLE ROCKS

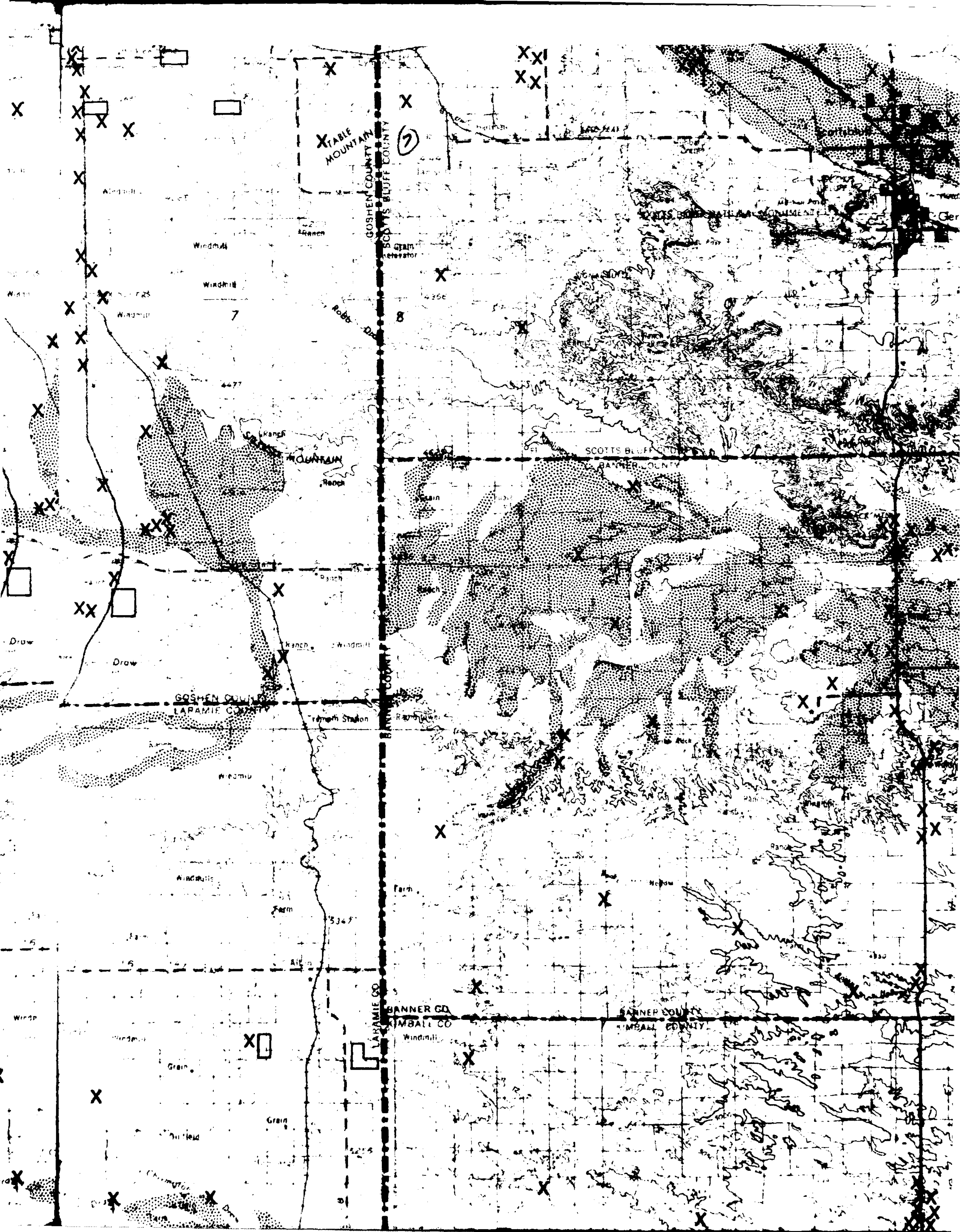
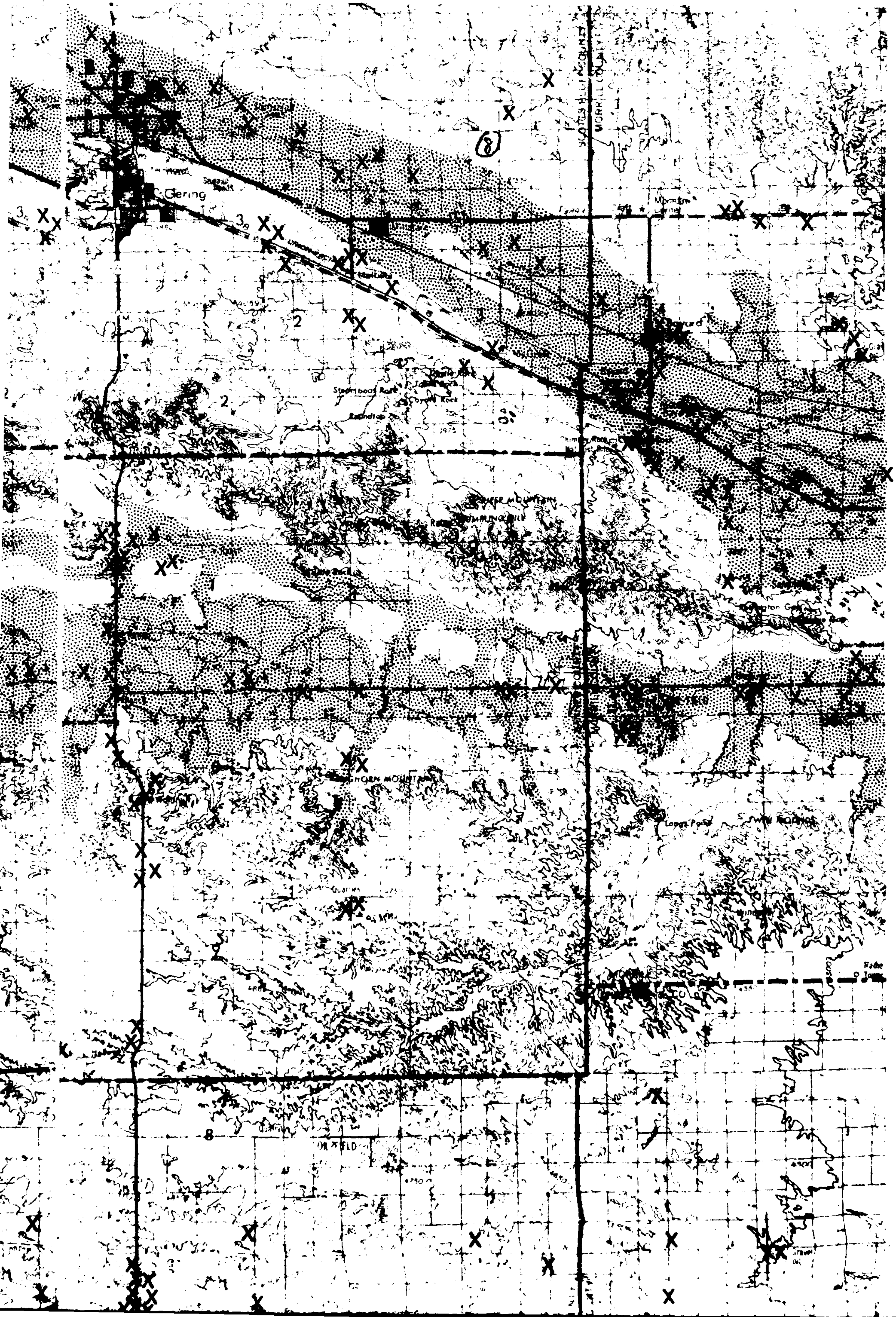
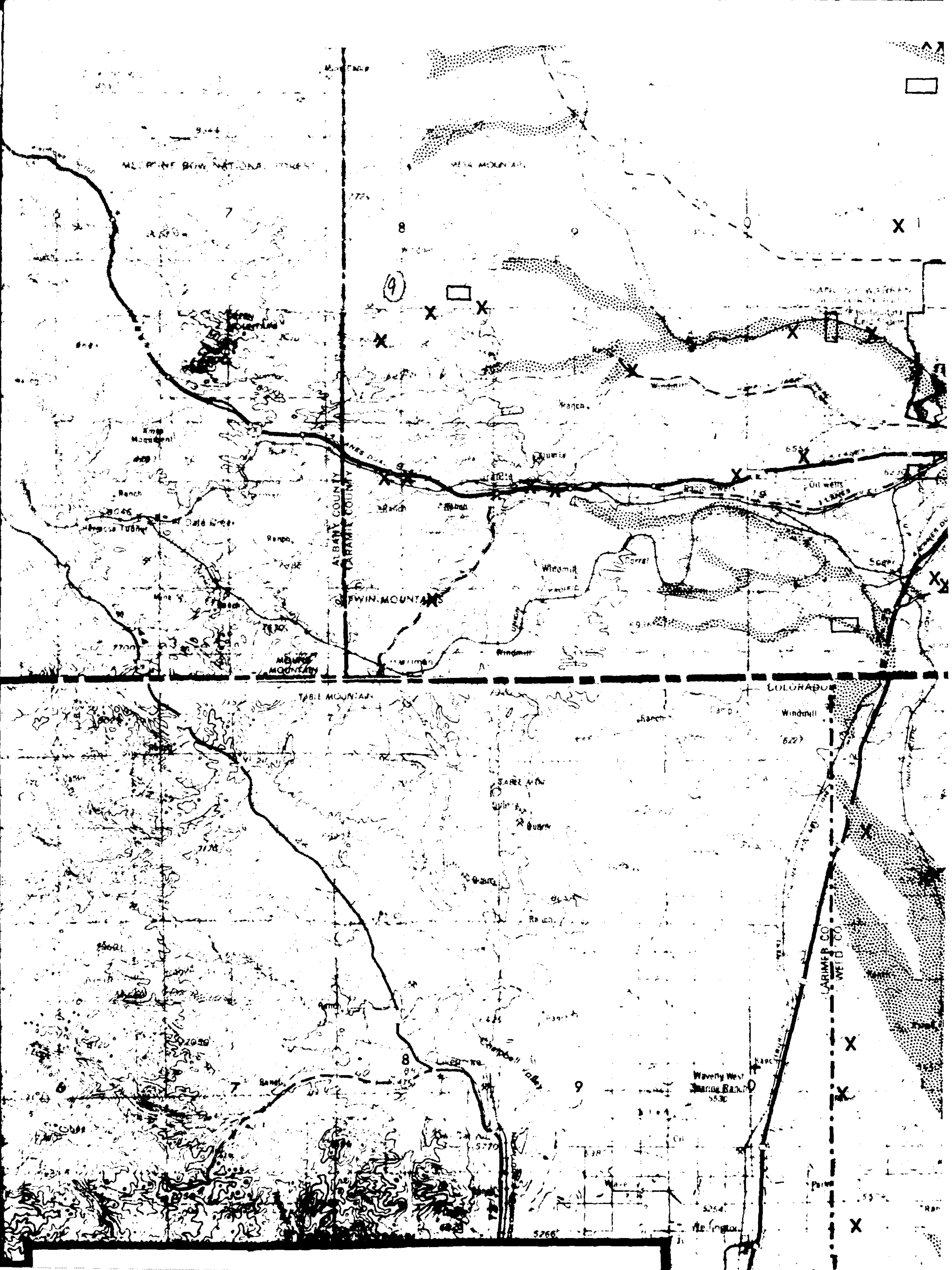
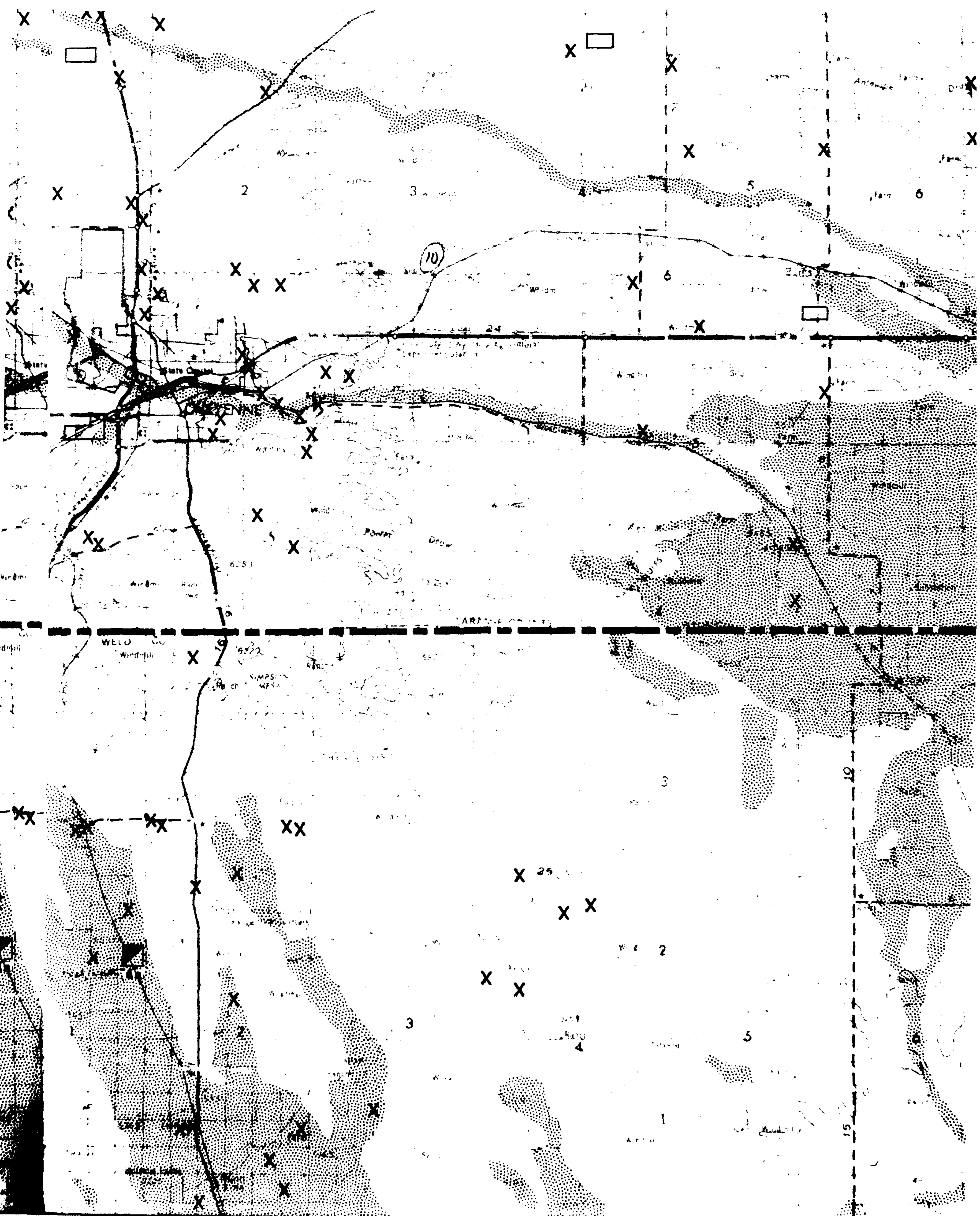


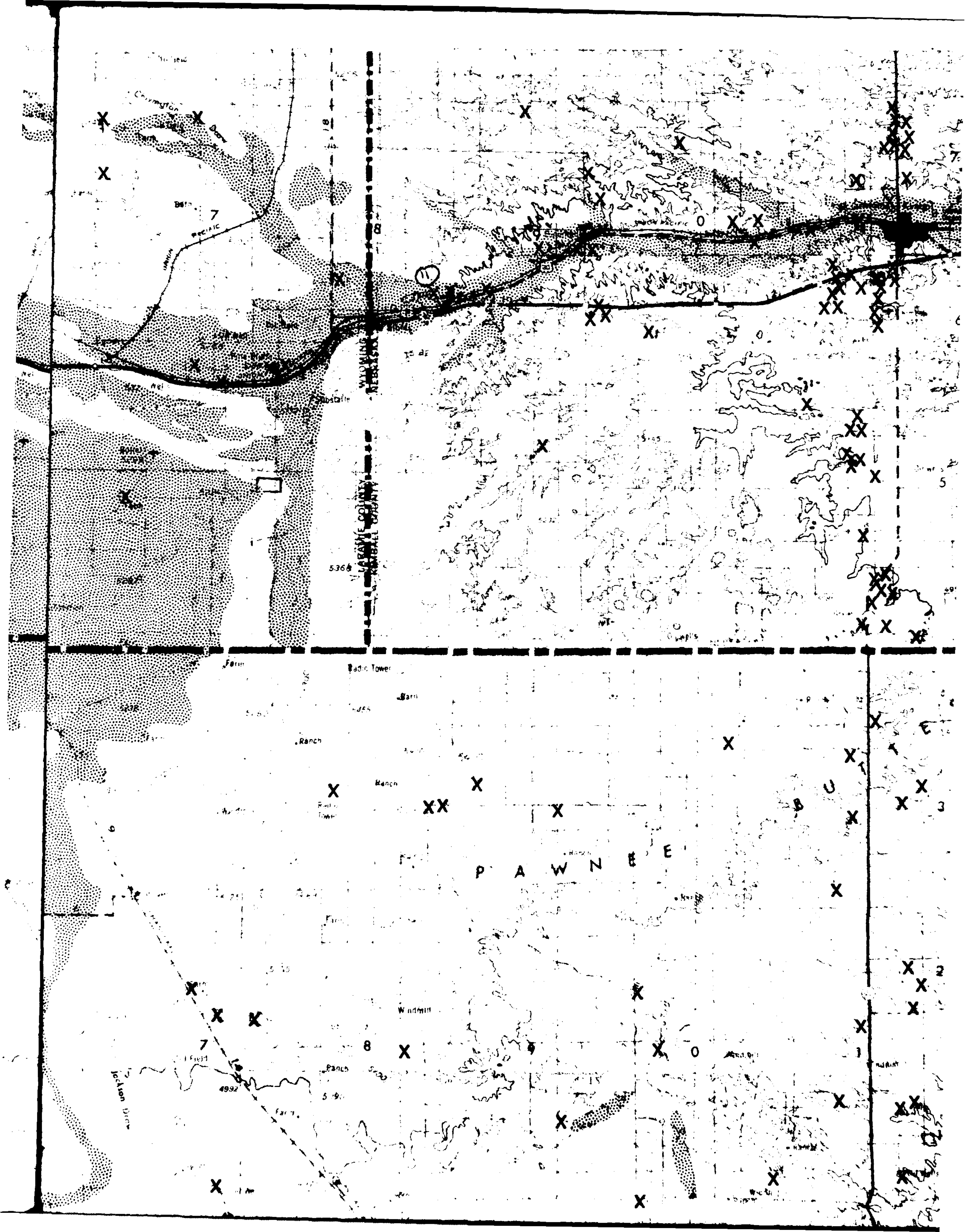
TABLE MOUNTAIN
GOSHEN COUNTY
SCOTTS BLUFF COUNTY
7
8
Windmill
Ranch
Grain elevator
Drow
SCOTTS BLUFF COUNTY
BANNER COUNTY
GOSHEN COUNTY
LARAMIE COUNTY
Farm
Grain
LARAMIE CO
BANNER CO.
KIMBALL CO
BANNER COUNTY
KIMBALL COUNTY


(8)
Gering

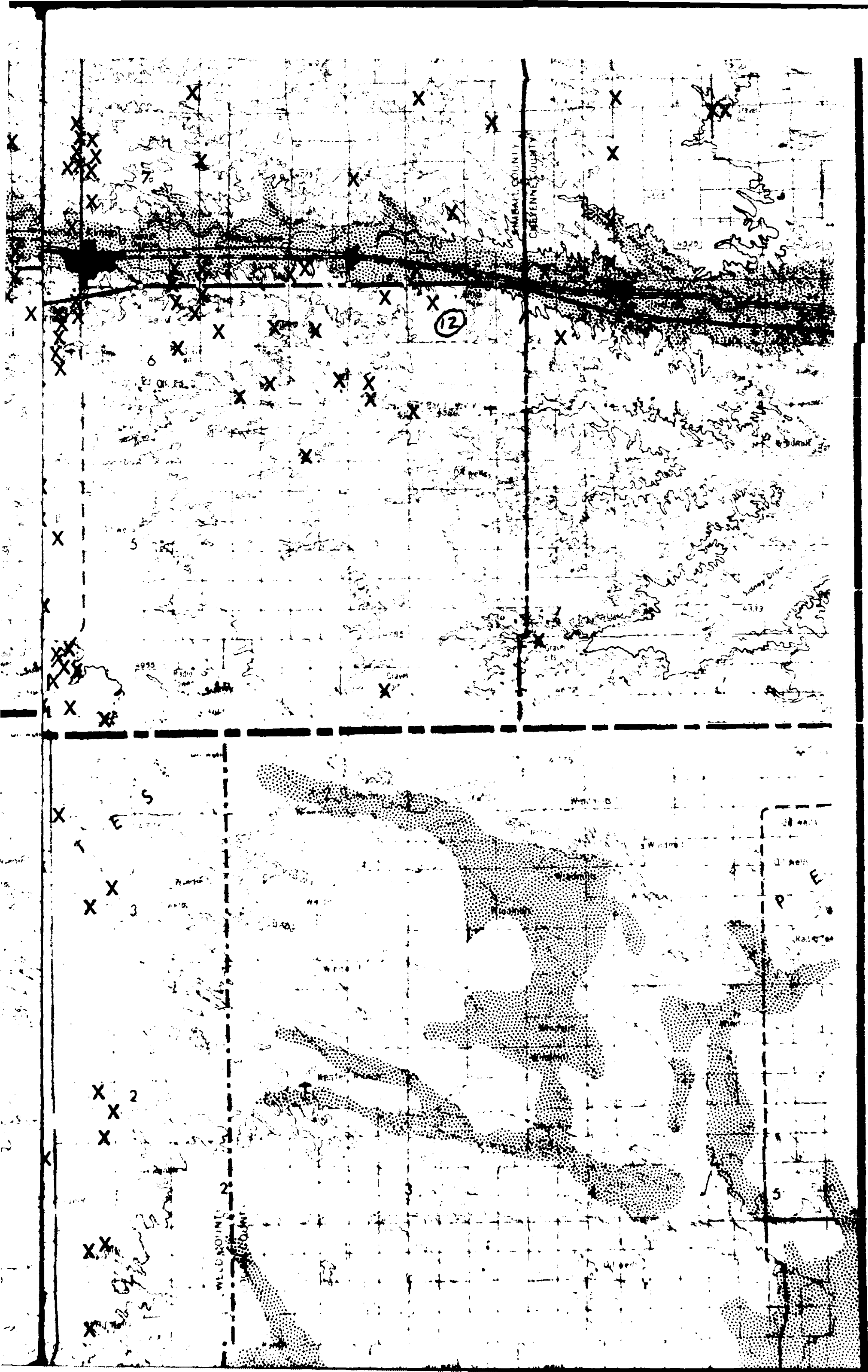


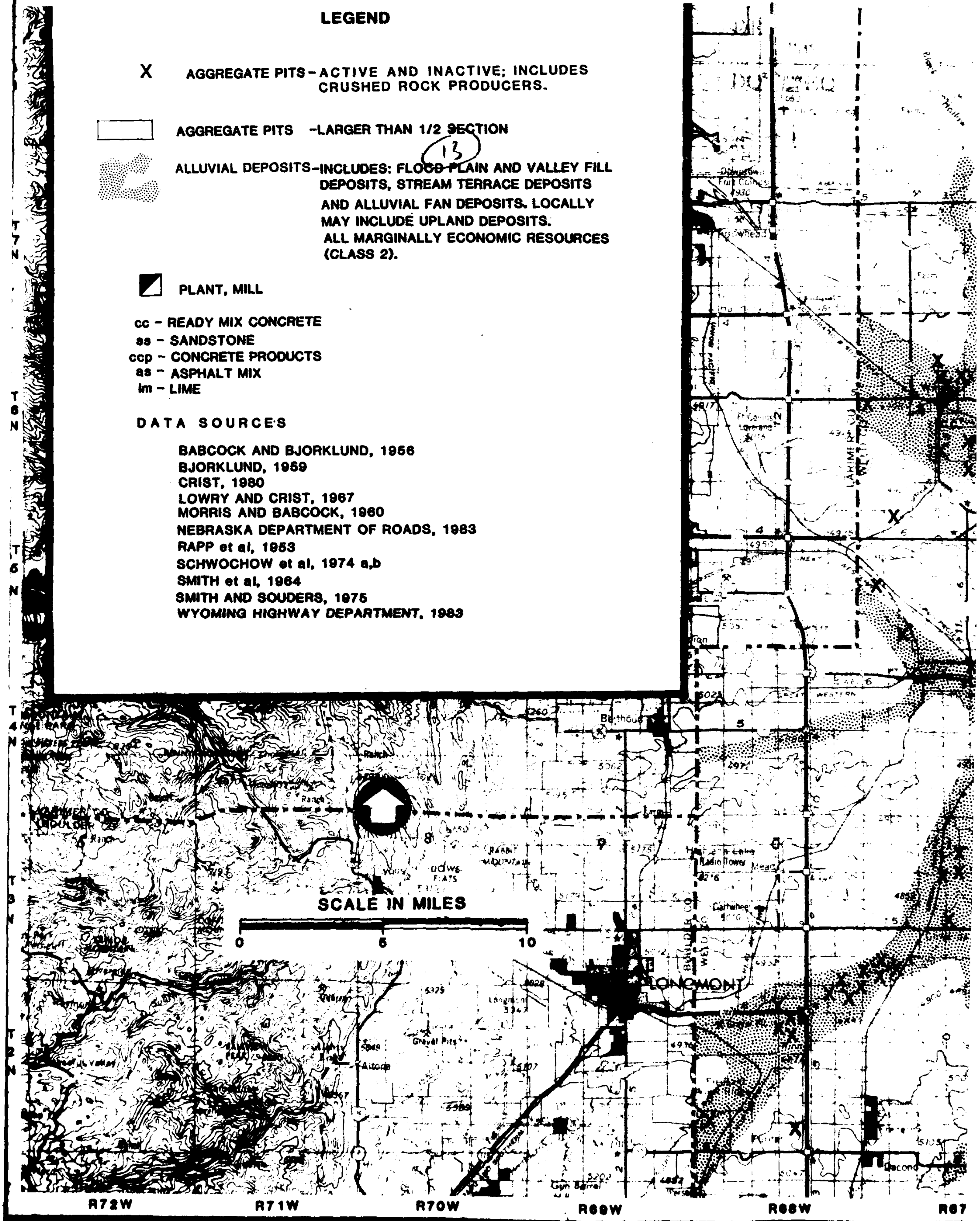
MESA MOUNTAIN
ALBANY COUNTY
LARAMIE COUNTY
Ranch
Windmill
Corral
Oil wells
Harriman
COLORADO
TABLE MOUNTAIN
LARIMER CO
WELD CO
Campbell Valley
Waverly West

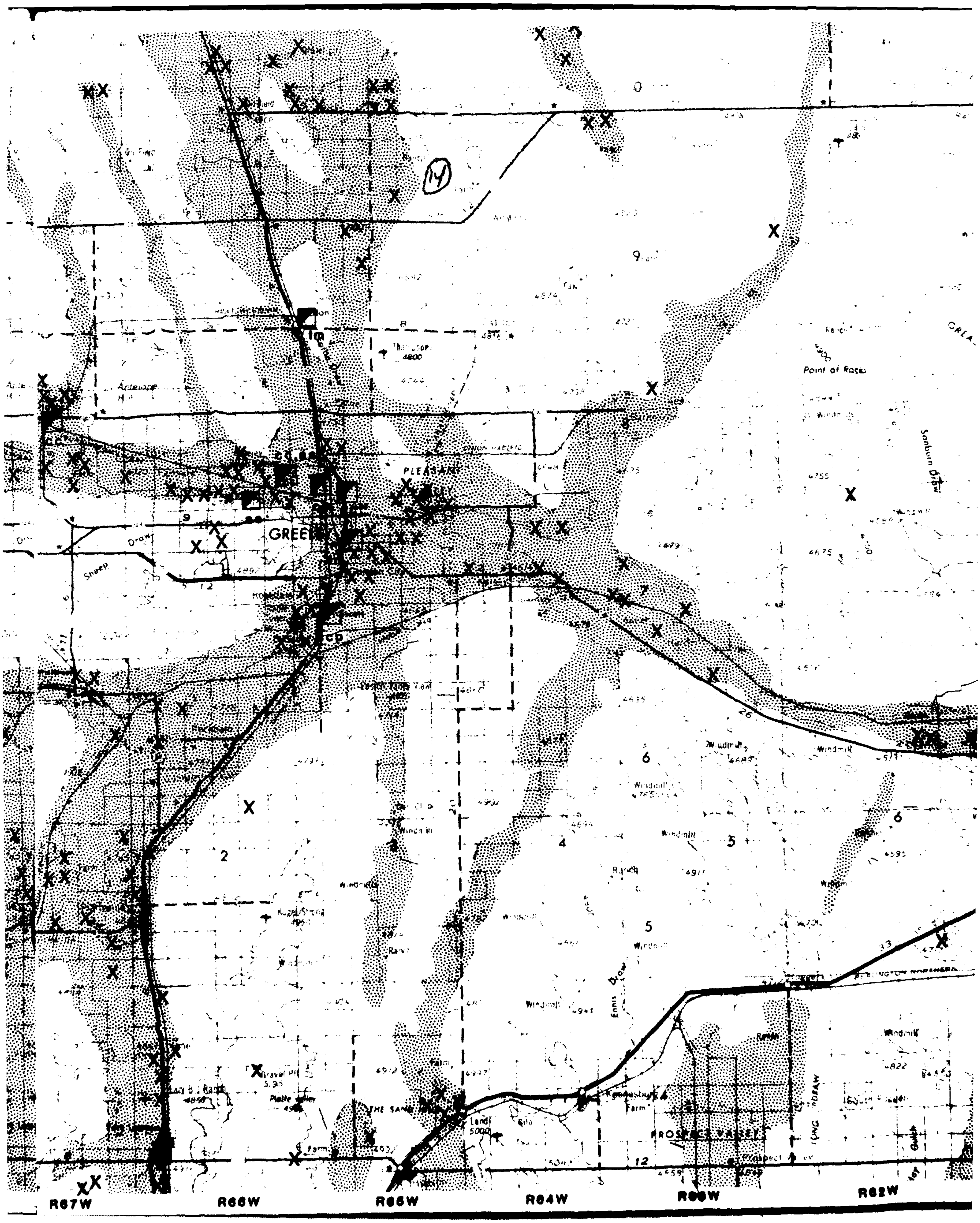

CHEYENNE
State Capitol
24
WELD CO
LARAMIE CO
Windmill
Porter
Draw
SIMPSON
MESA
10
15



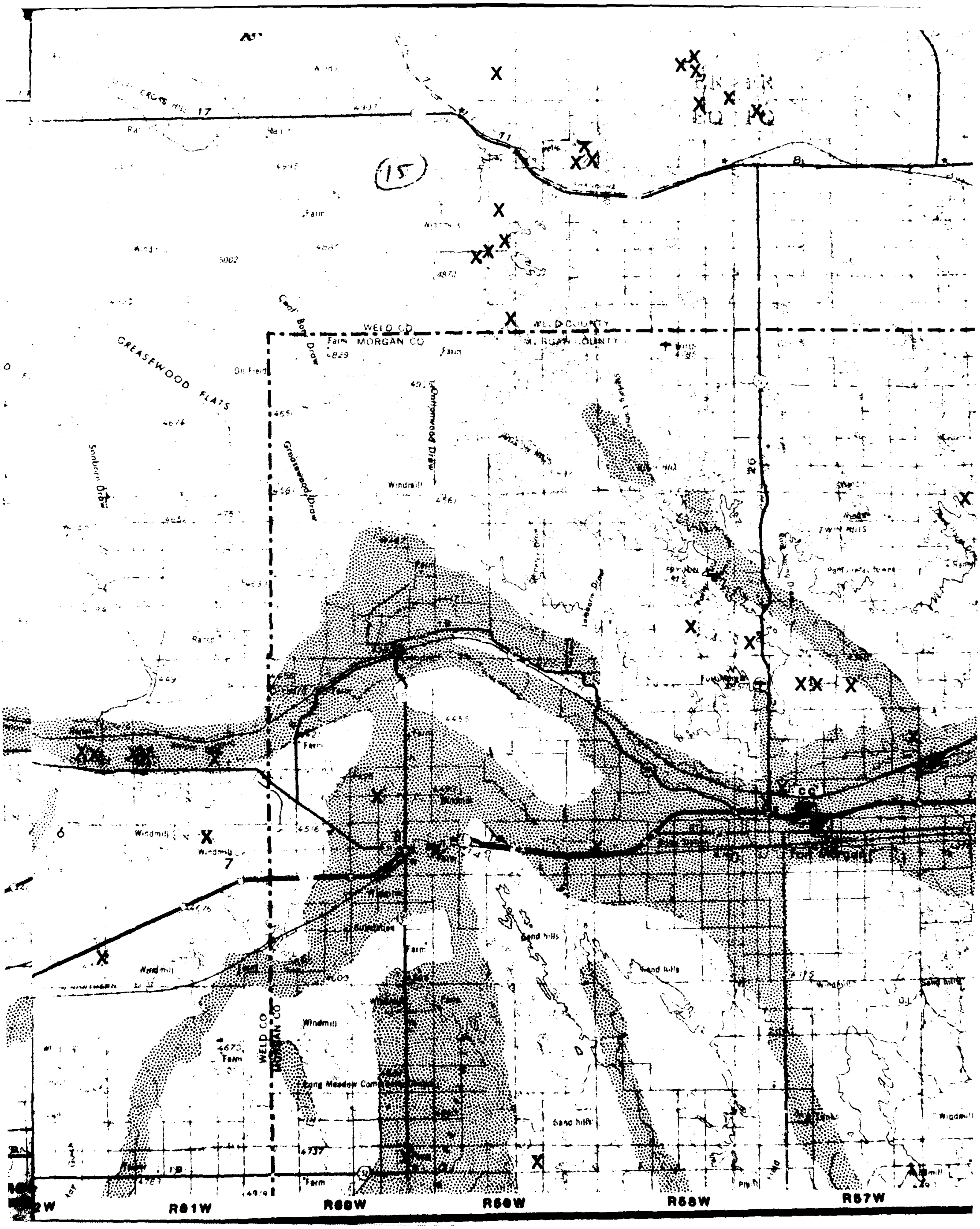
WYOMING
NEBRASKA
LARAMIE COUNTY
KIMBALL COUNTY
P A W N E E
B U T T E
Radio Tower
Ranch
Windmill
Farm
Barn
5368
4992
Jackson Draw


KIMBALL COUNTY
CHEYENNE COUNTY

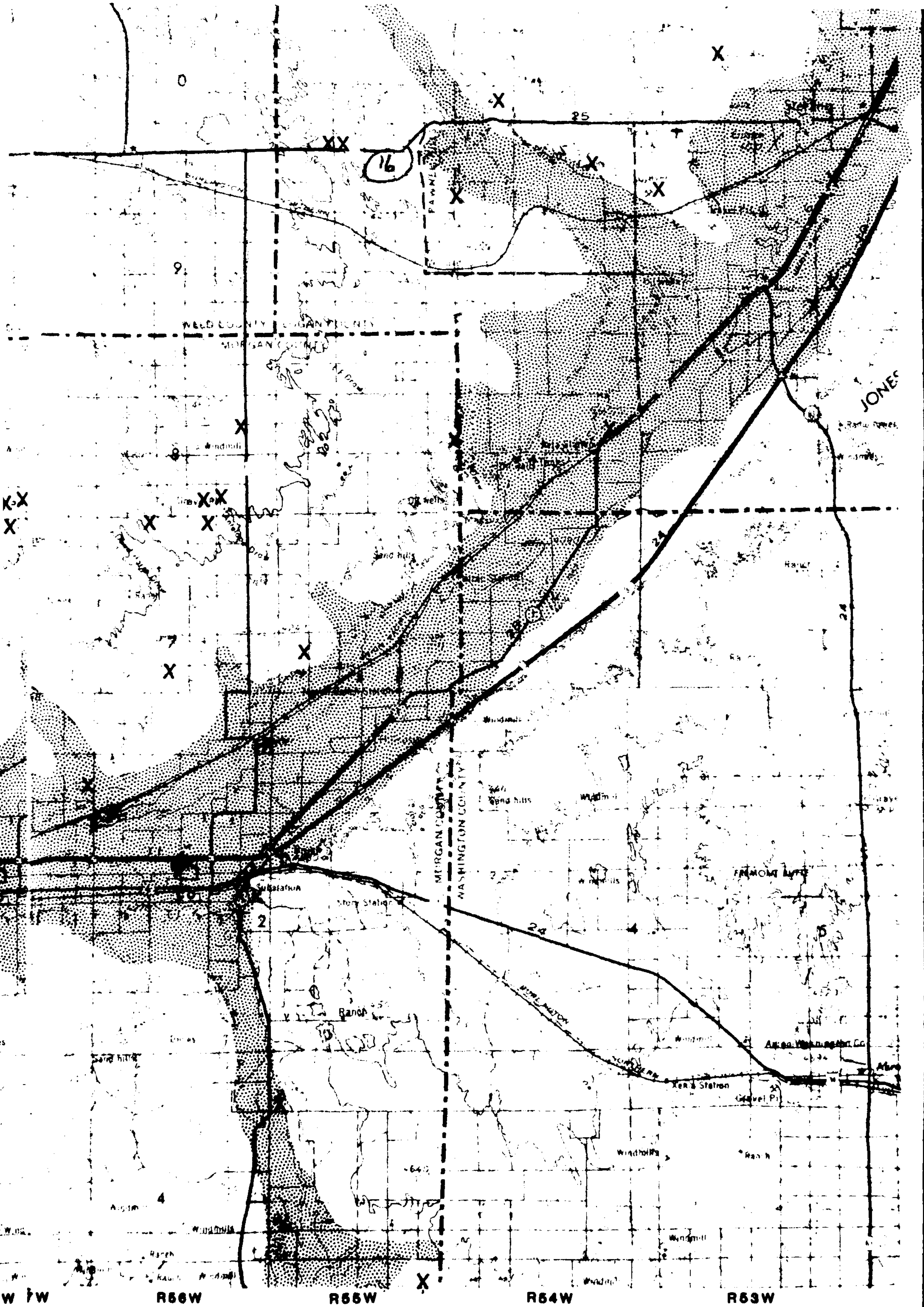

LEGEND
X AGGREGATE PITS-ACTIVE AND INACTIVE; INCLUDES CRUSHED ROCK PRODUCERS.
AGGREGATE PITS -LARGER THAN 1/2 SECTION
13
ALLUVIAL DEPOSITS-INCLUDES: FLOOD PLAIN AND VALLEY FILL DEPOSITS, STREAM TERRACE DEPOSITS AND ALLUVIAL FAN DEPOSITS. LOCALLY MAY INCLUDE UPLAND DEPOSITS. ALL MARGINALLY ECONOMIC RESOURCES (CLASS 2).
PLANT, MILL
cc - READY MIX CONCRETE
ss - SANDSTONE
ccp - CONCRETE PRODUCTS
as - ASPHALT MIX
lm - LIME
DATA SOURCES
BABCOCK AND BJORKLUND, 1956
BJORKLUND, 1959
CRIST, 1980
LOWRY AND CRIST, 1967
MORRIS AND BABCOCK, 1960
NEBRASKA DEPARTMENT OF ROADS, 1983
RAPP et al, 1953
SCHWOCHOW et al, 1974 a,b
SMITH et al, 1964
SMITH AND SOUDERS, 1975
WYOMING HIGHWAY DEPARTMENT, 1983
SCALE IN MILES
0
5
10
T 7 N
T 6 N
T 5 N
T 4 N
T 3 N
T 2 N
R72W
R71W
R70W
R69W
R68W
R67
LONGMONT
LARIMER CO
WELD CO
BOULDER CO
Berthoud
Gravel Pits



14
Antelope Hill
Point of Rocks
Sanborn Draw
PLEASANT
GREE
Sheep Draw
Ennis Draw
PROSPECT VALLEY
THE SAND
Windmill
Ranch
Farm
Gravel Pit
Platte Valley
Keenesburg
R67W
R66W
R65W
R64W
R62W

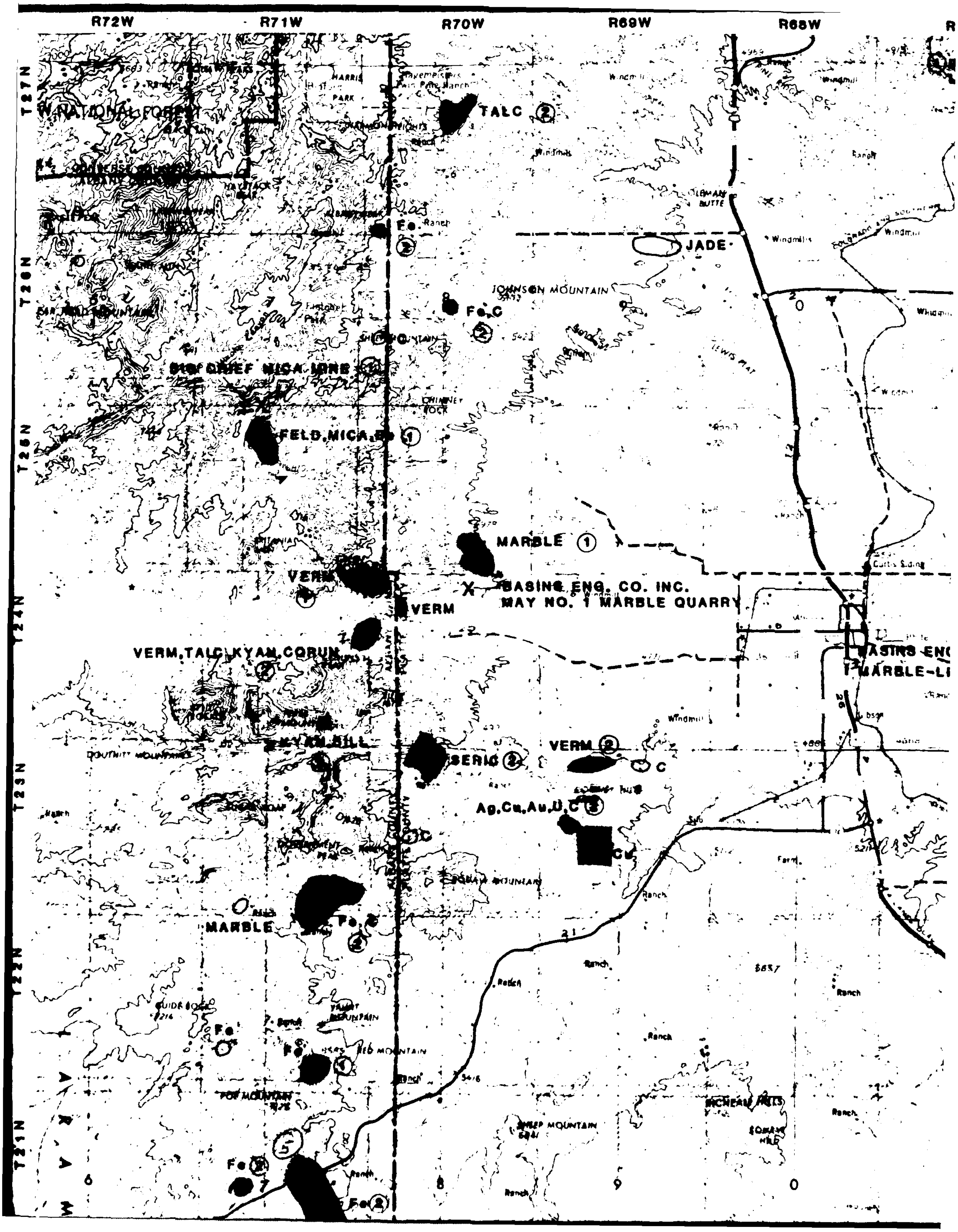


15
GREASEWOOD FLATS
WELD CO
MORGAN CO
WELD COUNTY
MORGAN COUNTY
Oil Field
Greasewood Draw
Cottonwood Draw
Sanborn Draw
Windmill
Farm
Ranch
TWIN HILLS
Sand hills
Long Meadow Community
Fort Morgan
Substation
4829
4785
4673
4737
R61W
R60W
R59W
R58W
R57W

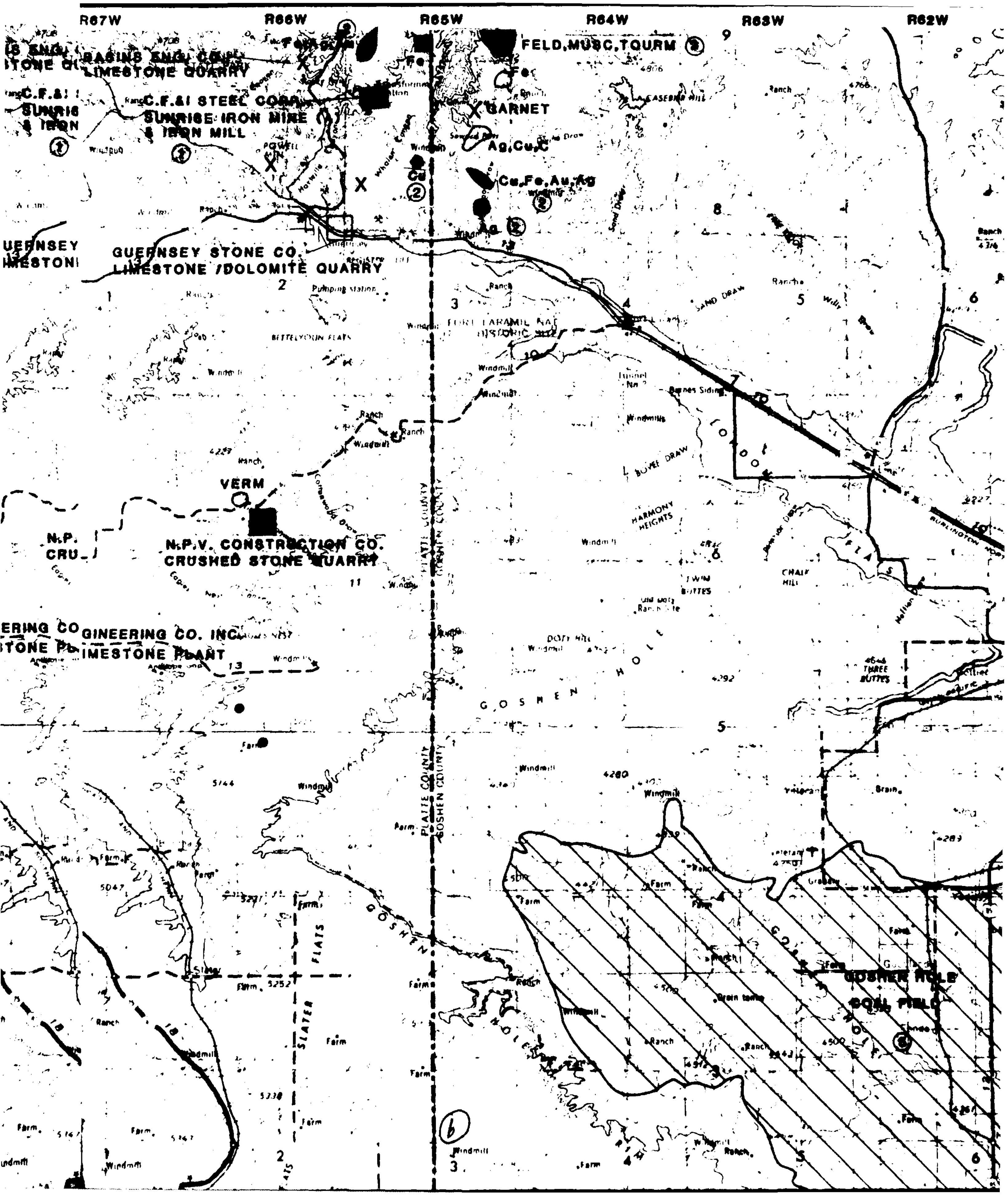


20

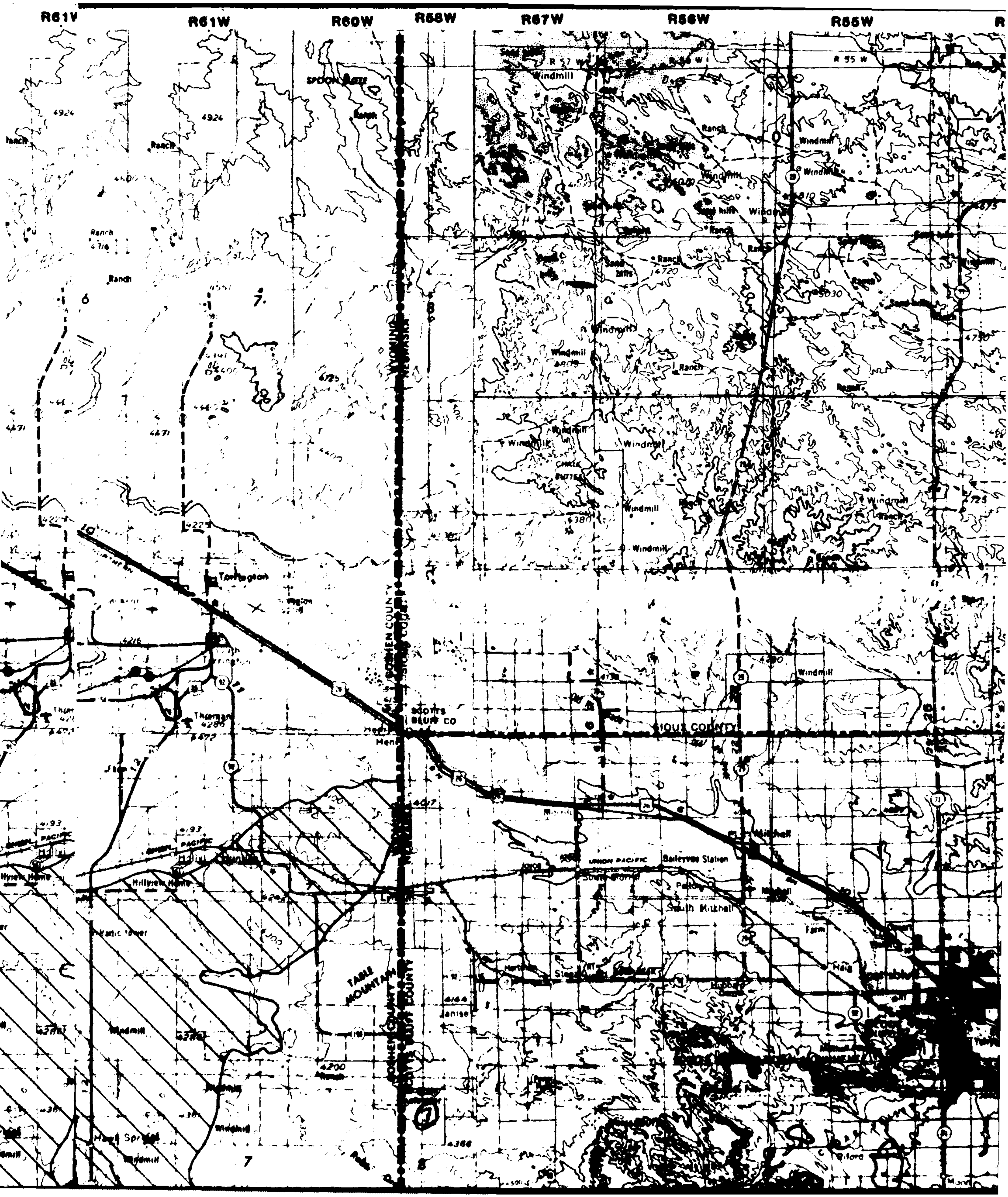
FIGURE NO. 2.6.3-1

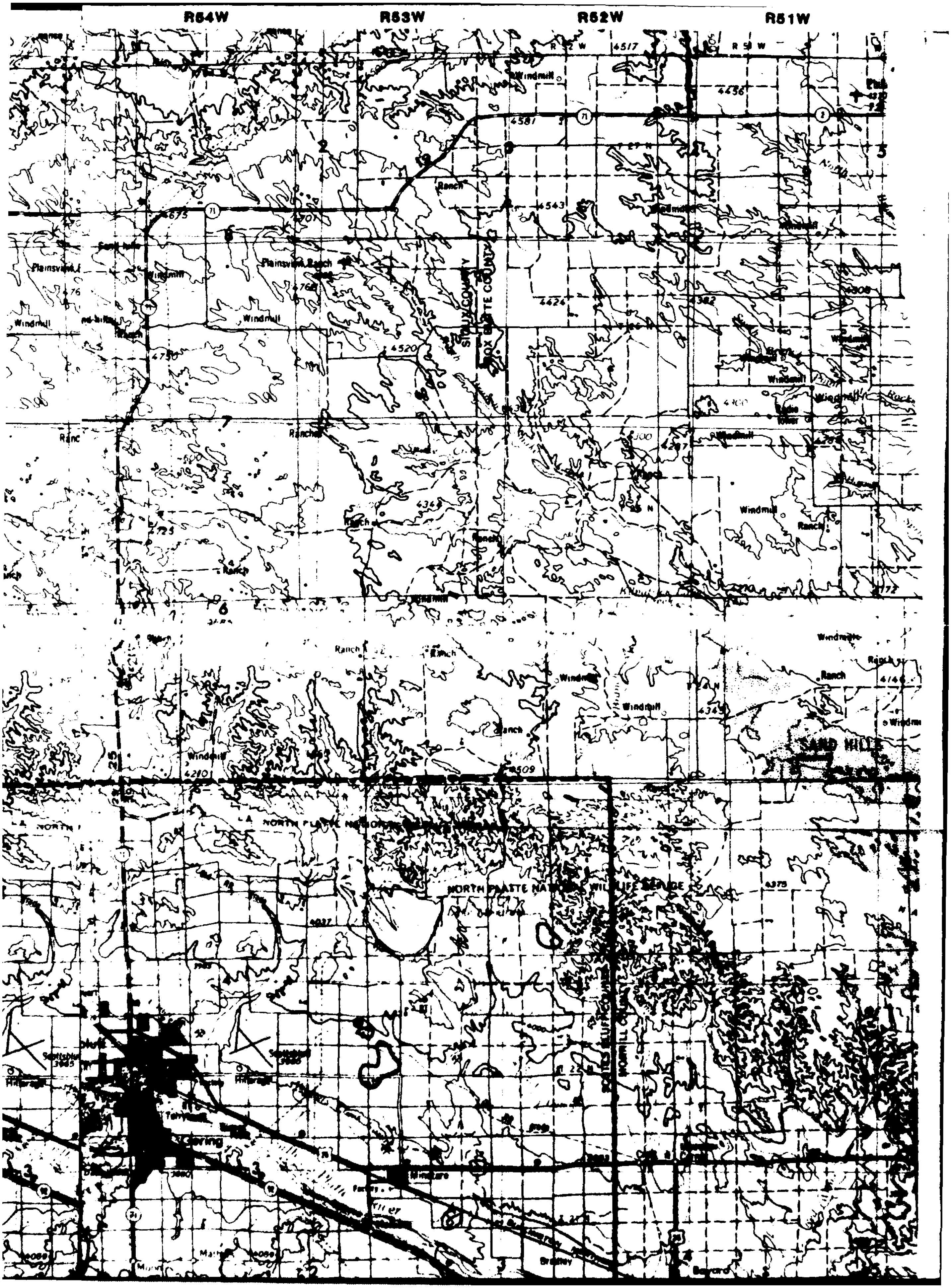


R72W
R71W
R70W
R69W
R68W
T27N
T26N
T25N
T24N
T23N
T22N
T21N
TALC 2
Fe. 2
JADE
JOHNSON MOUNTAIN
Fe,C 2
SHEEP MOUNTAIN
CHIMNEY ROCK
FELD,MICA 1
MARBLE 1
VERM
BASINS ENG. CO. INC.
MAY NO. 1 MARBLE QUARRY
VERM
VERM,TALC,KYAN,CORUN 2
SERIC 2
VERM 2
C
Ag,Cu,Au,U,C 2
Cu
C
MARBLE
Fe 2
Fe
Fe 1
RED MOUNTAIN
SHEEP MOUNTAIN
Fe 2
Fe 2
Ranch
Windmill

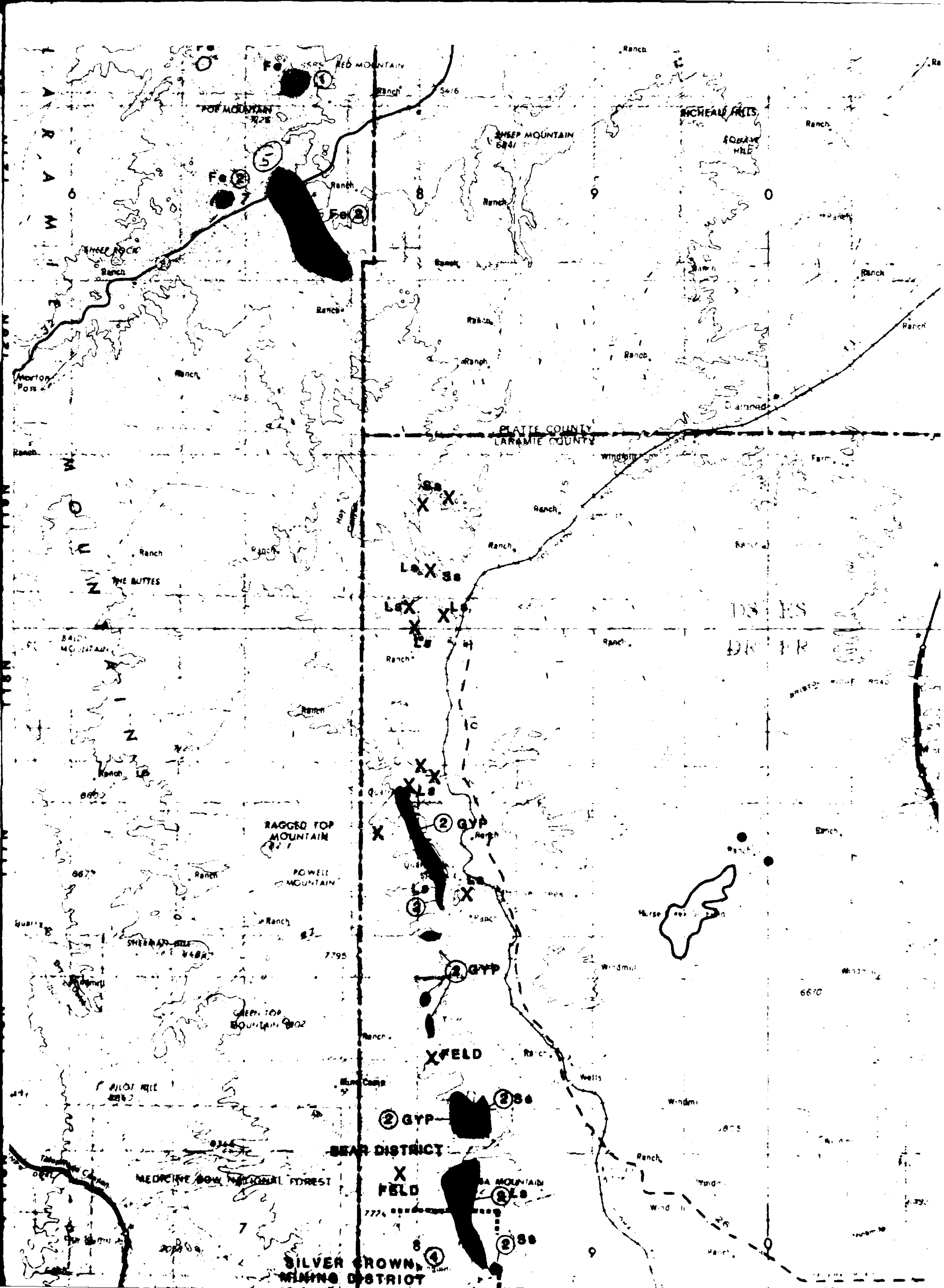


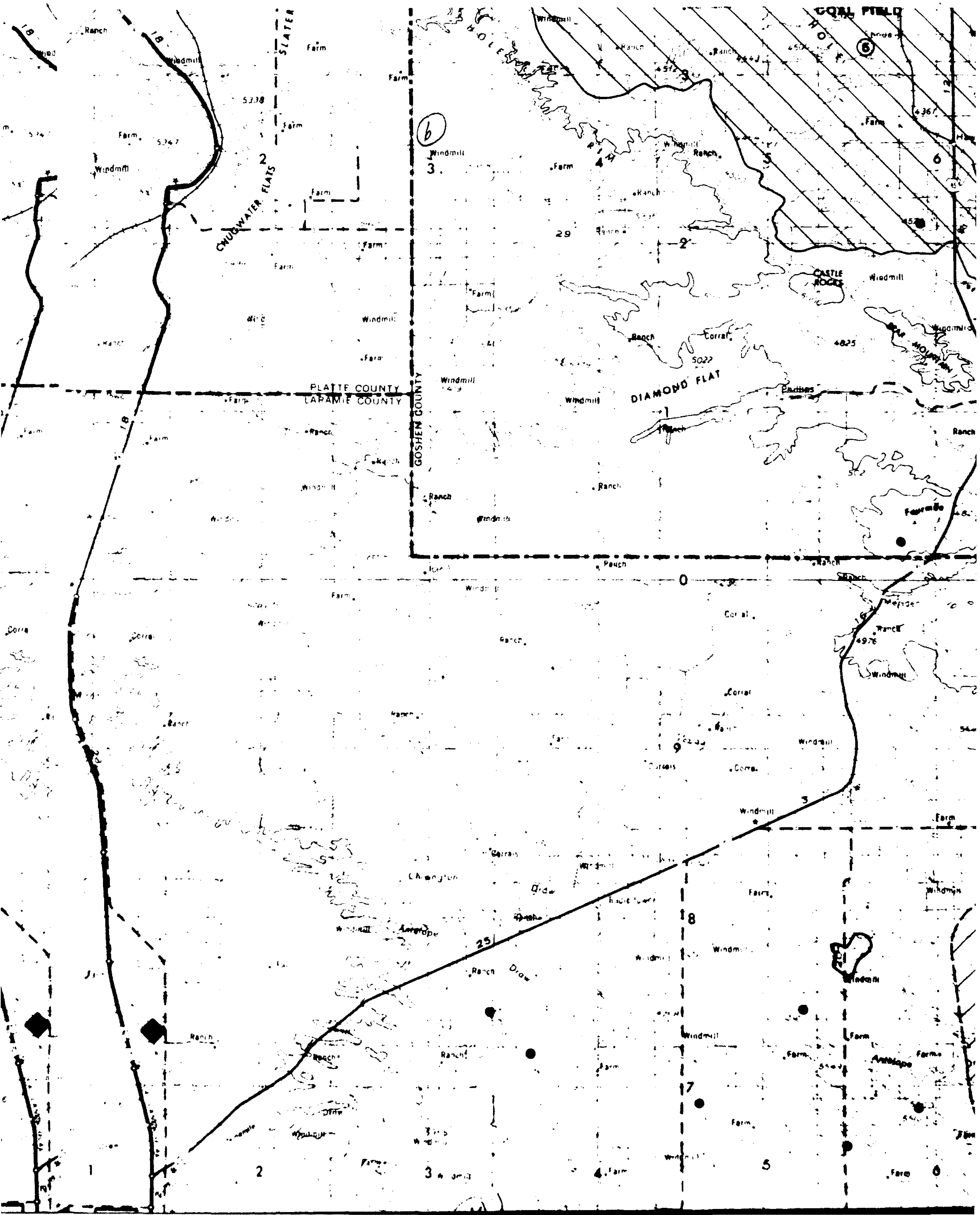
R67W
R66W
R65W
R64W
R63W
R62W
FELD,MUSC,TOURM
BASINS ENGR CO.
LIMESTONE QUARRY
C.F.&I STEEL CORP.
SUNRISE IRON MINE
& IRON MILL
GARNET
Ag,Cu,C
Cu,Fe,Au,Ag
GUERNSEY STONE CO.
LIMESTONE /DOLOMITE QUARRY
FORT LARAMIE NAT
HISTORIC SITE
BETTELYOUN FLATS
VERM
N.P.V. CONSTRUCTION CO.
CRUSHED STONE QUARRY
HARMONY HEIGHTS
TWIN BUTTES
CHALK HILL
DOTY HILL
THREE BUTTES
GINEERING CO. INC.
IMESTONE PLANT
G O S H E N
H O L E
PLATTE COUNTY
GOSHEN COUNTY
SLATER FLATS
GOSHEN HOLE
COAL FIELD
BURLINGTON NORTHERN


R61W
R61W
R60W
R58W
R57W
R56W
R55W
R 57 W
R 56 W
R 55 W
SPOON BUTTE
Ranch
Windmill
Sand Hills
CHALK BUTTES
Torrington
SIOUX COUNTY
GOSHEN COUNTY
SCOTTS BLUFF CO
SCOTTS BLUFF COUNTY
WYOMING
NEBRASKA
UNION PACIFIC
Mitchell
South Mitchell
Hillview Home
TABLE MOUNTAIN
Janise
Hawk Springs
Farm
Bayard Station
4924
4716
4671
4225
4216
4193
4720
5030
4380
4290
4017
4200
4386
6
7
8

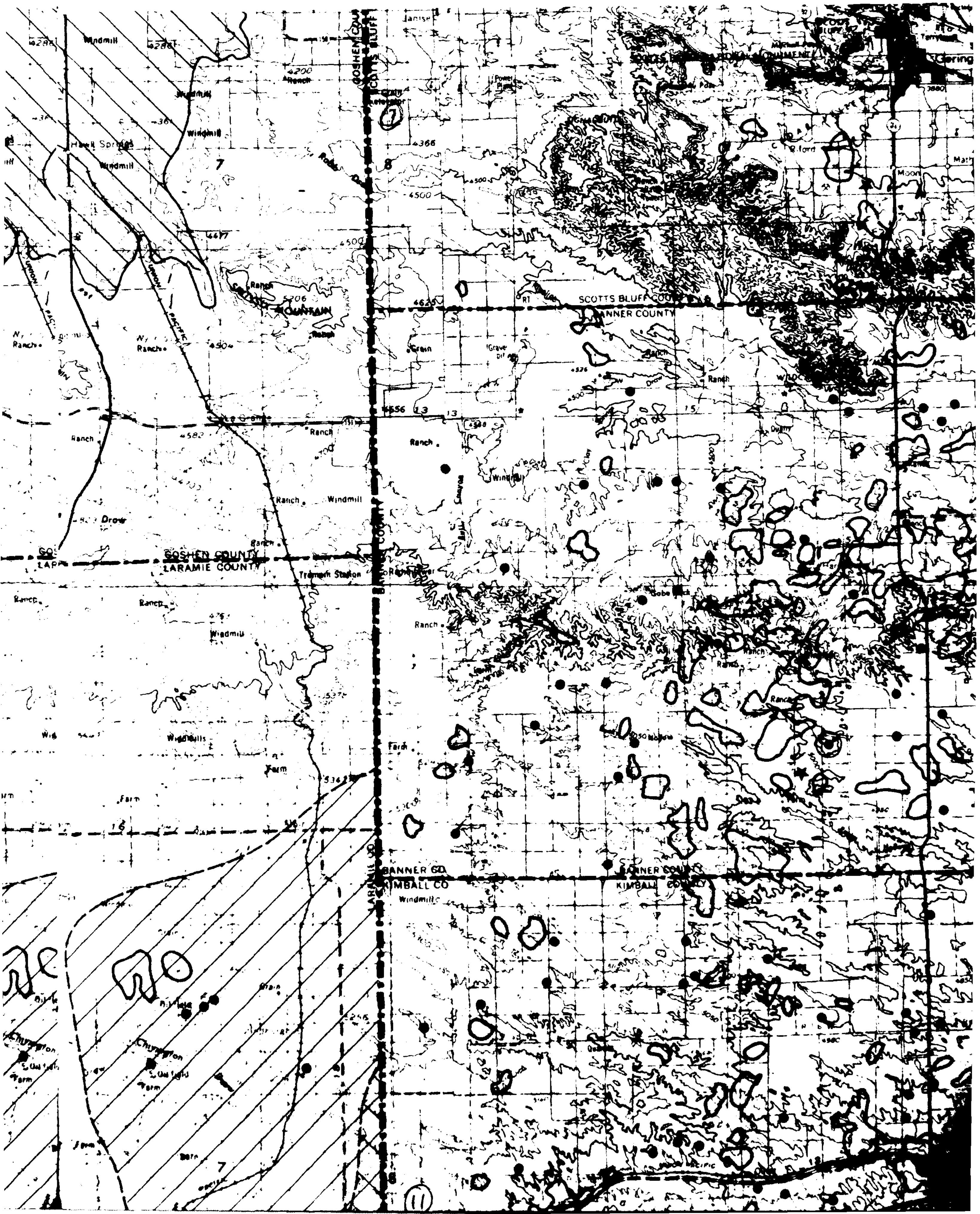


R54W
R53W
R52W
R51W
Windmill
Ranch
Plainsview Ranch
SIOUX COUNTY
BOX BUTTE COUNTY
Radio Tower
SAND HILLS
NORTH PLATTE NATIONAL WILDLIFE REFUGE
SCOTTS BLUFF COUNTY
MORRILL COUNTY
Scottsbluff
Terrytown
Gering
Minatare
Bradley
Bayard

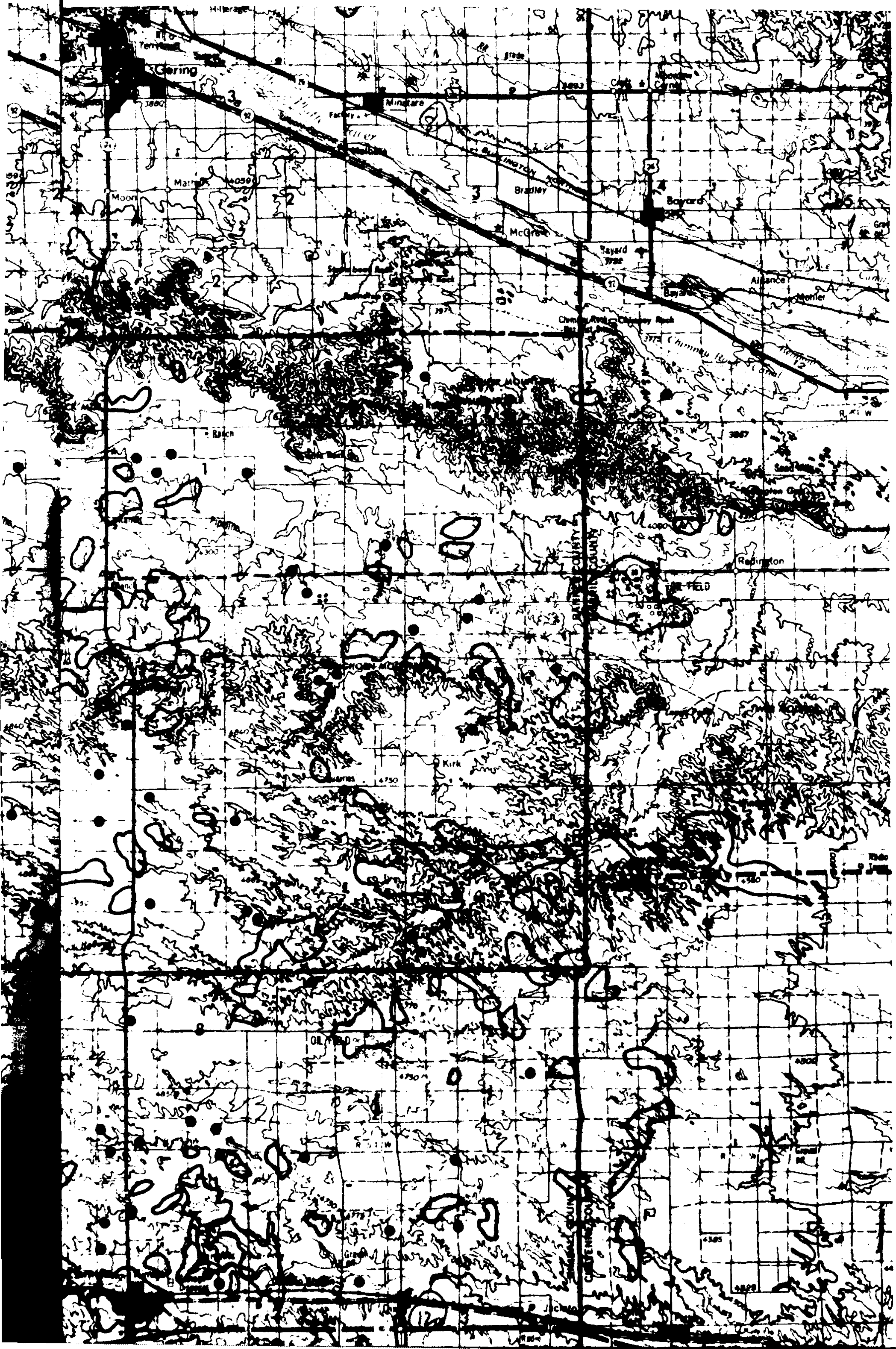

RED MOUNTAIN
POE MOUNTAIN
SHEEP MOUNTAIN
SHEEP ROCK
Morton Pass
PLATTE COUNTY
LARAMIE COUNTY
THE BUTTES
RAGGED TOP MOUNTAIN
POWELL MOUNTAIN
SHERMAN HILL
GYP
FELD
BEAR DISTRICT
MEDICINE BOW NATIONAL FOREST
SILVER CROWN MINING DISTRICT
Ranch
Windmill
Wells

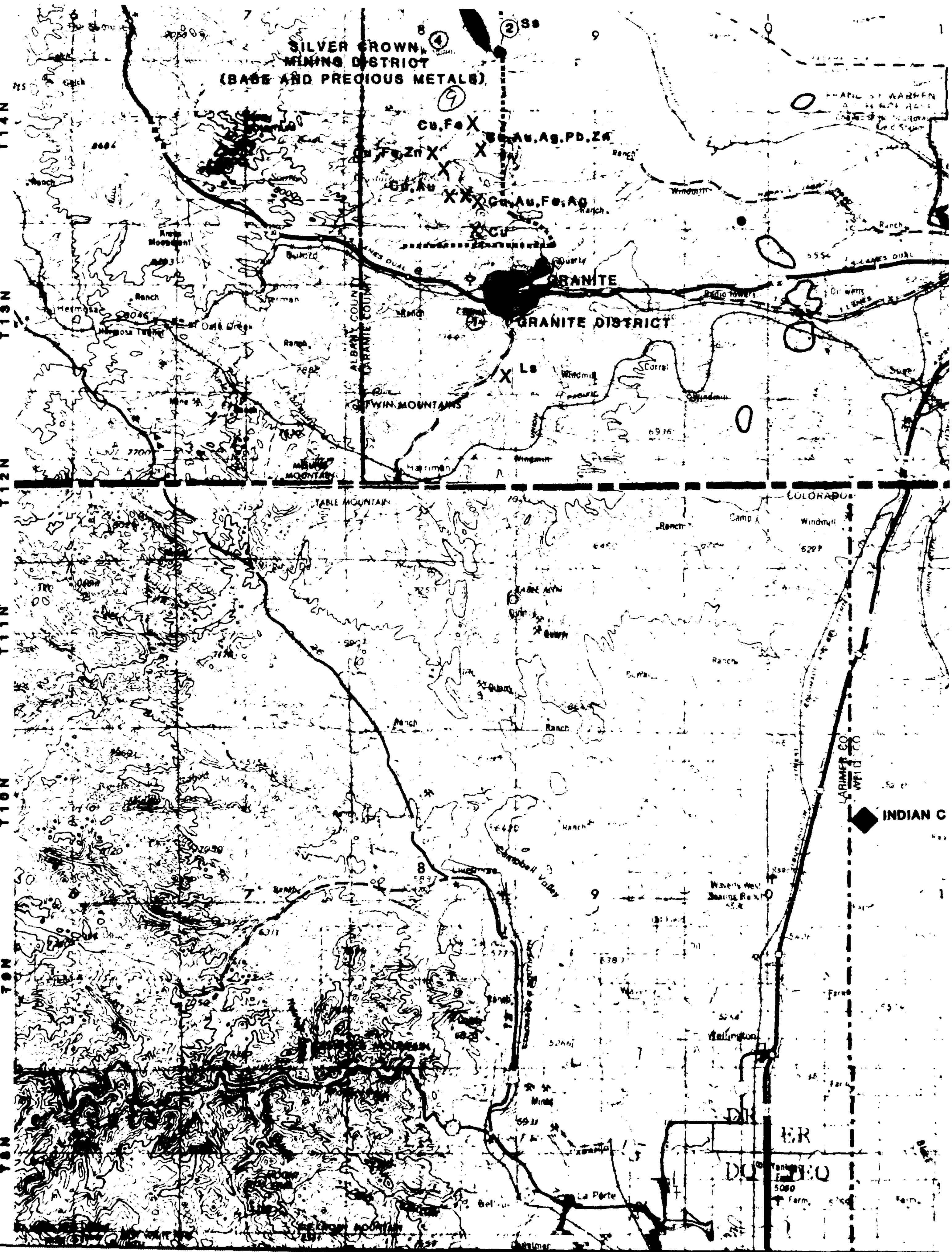


COAL FIELD
CHUGWATER FLATS
SLATER
PLATTE COUNTY
LARAMIE COUNTY
GOSHEN COUNTY
CASTLE ROCKS
DIAMOND FLAT
Corral
Ranch
Farm
Windmill
Antelope
Draw
5022
4825
4976
5338
b

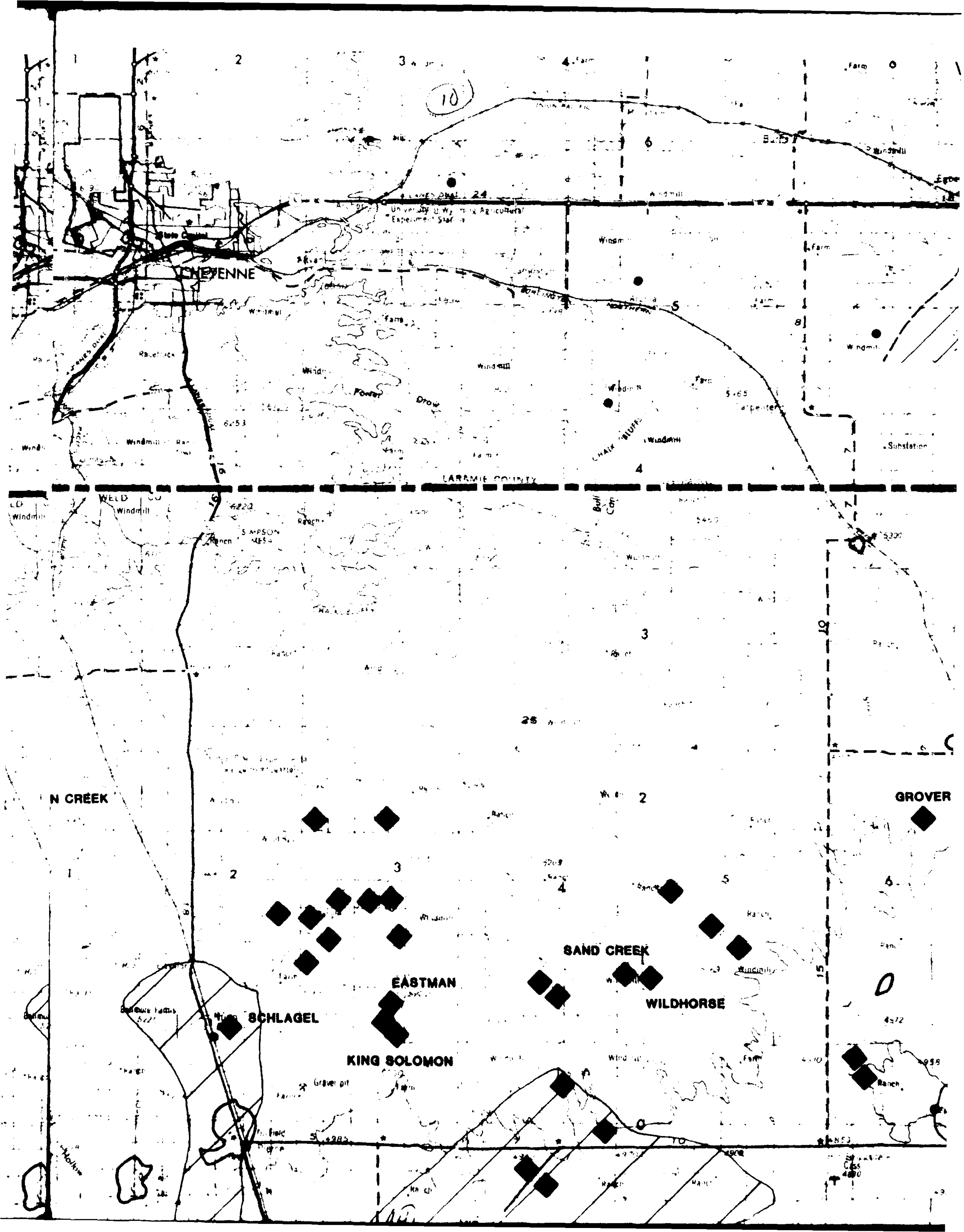


Windmill
Hawk Springs
7
8
4366
4500
4625
4656
SCOTTS BLUFF COUNTY
BANNER COUNTY
GOSHEN COUNTY
LARAMIE COUNTY
Tremain Station
Ranch
Windmill
Farm
BANNER CO
KIMBALL CO
KIMBALL COUNTY
Gering
11

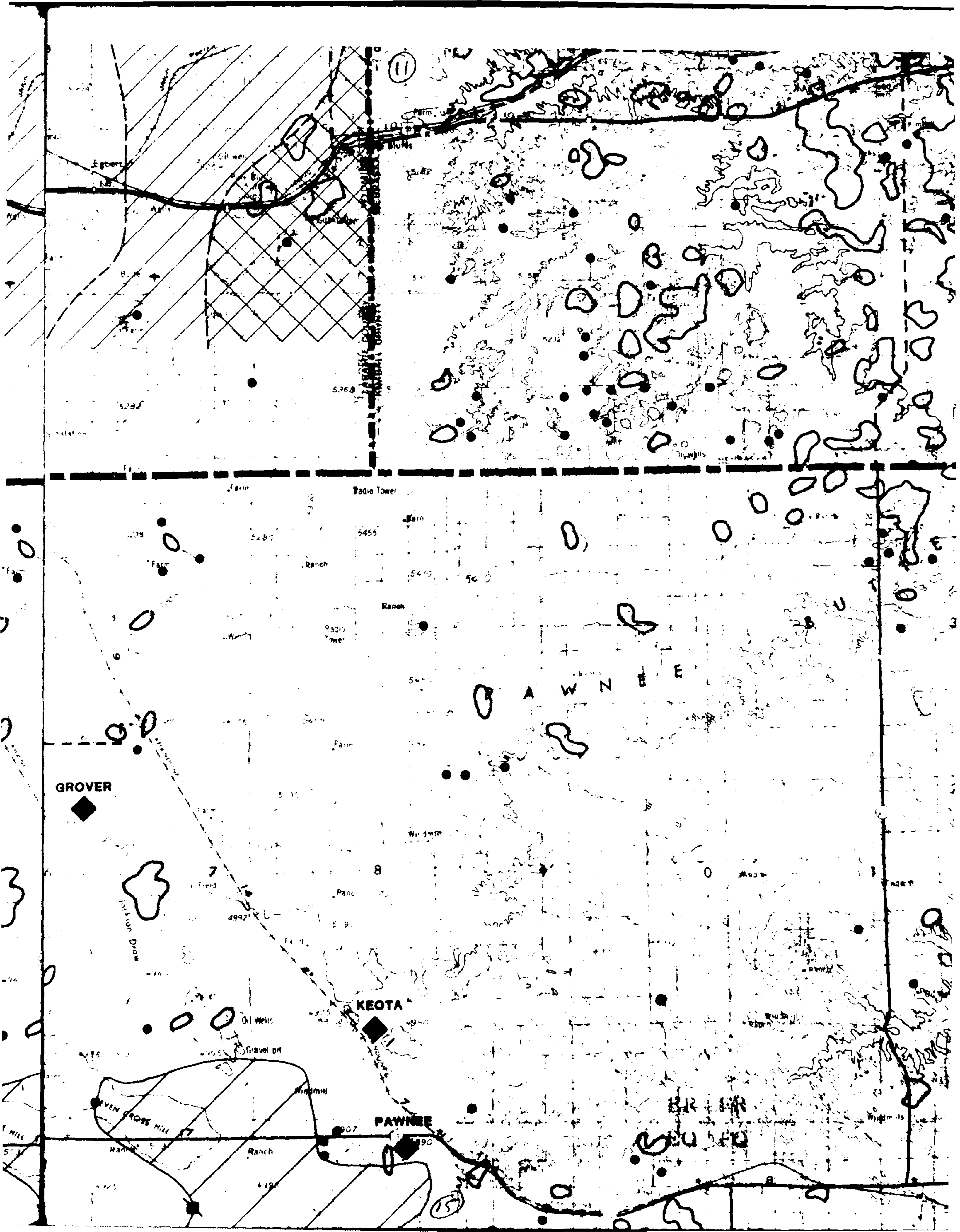

Gering
Minatare
Bradley
McGrew
Bayard
Alliance
Mohler
Moon
Redington
Kirk
OIL FIELD
R 51 W



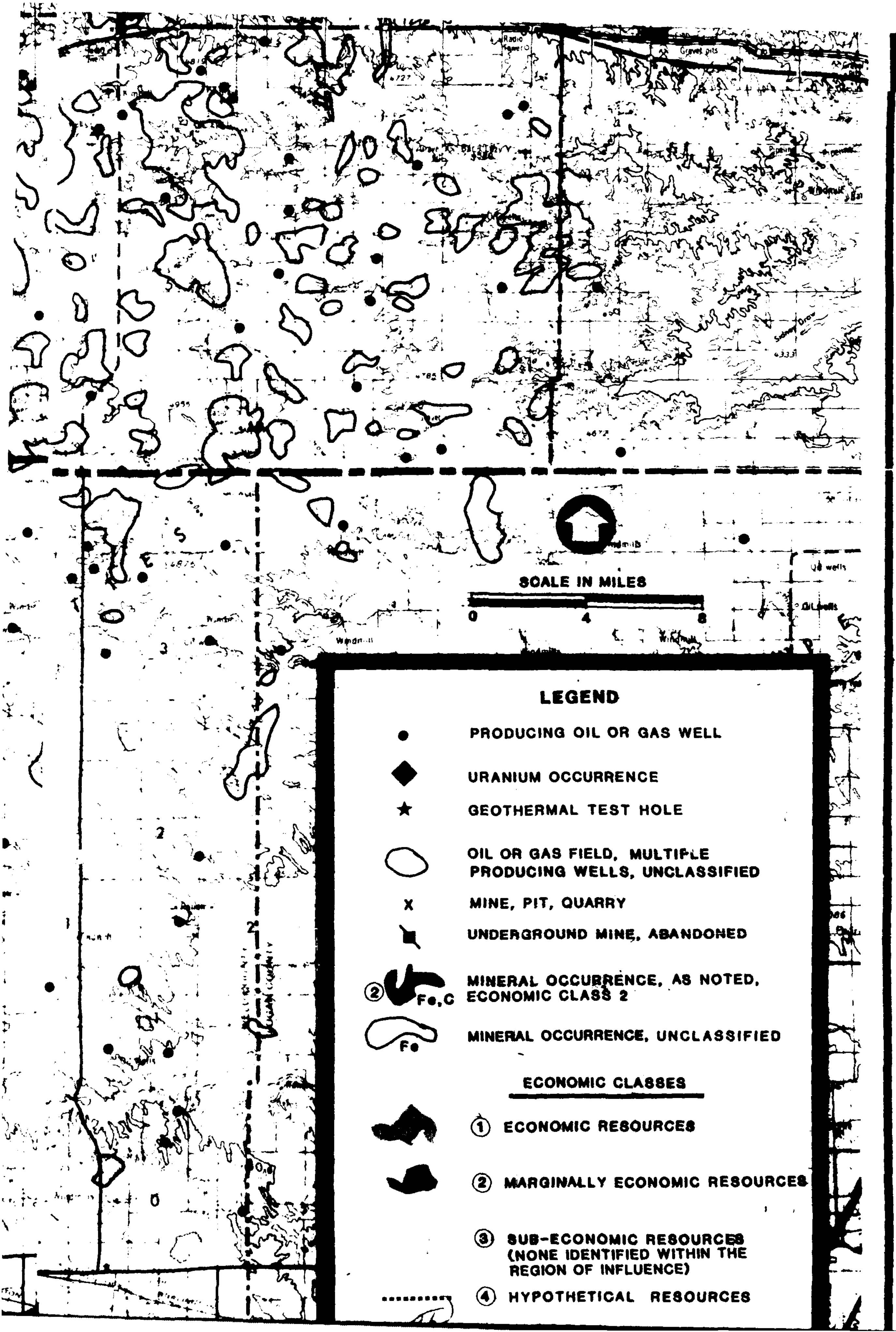
SILVER CROWN
MINING DISTRICT
(BASE AND PRECIOUS METALS)
Cu,Fe
Cu,Fe,Zn
Cu,Au
Cu,Au,Fe,Ag
Cu
Ls
GRANITE
GRANITE DISTRICT
TWIN MOUNTAINS
ALBANY COUNTY
LARAMIE COUNTY
Harriman
TABLE MOUNTAIN
COLORADO
LARIMER CO
WELD CO
INDIAN C
Campbell Valley
Wellington
La Porte
T14N
T13N
T12N
T11N
T10N
T9N
T8N



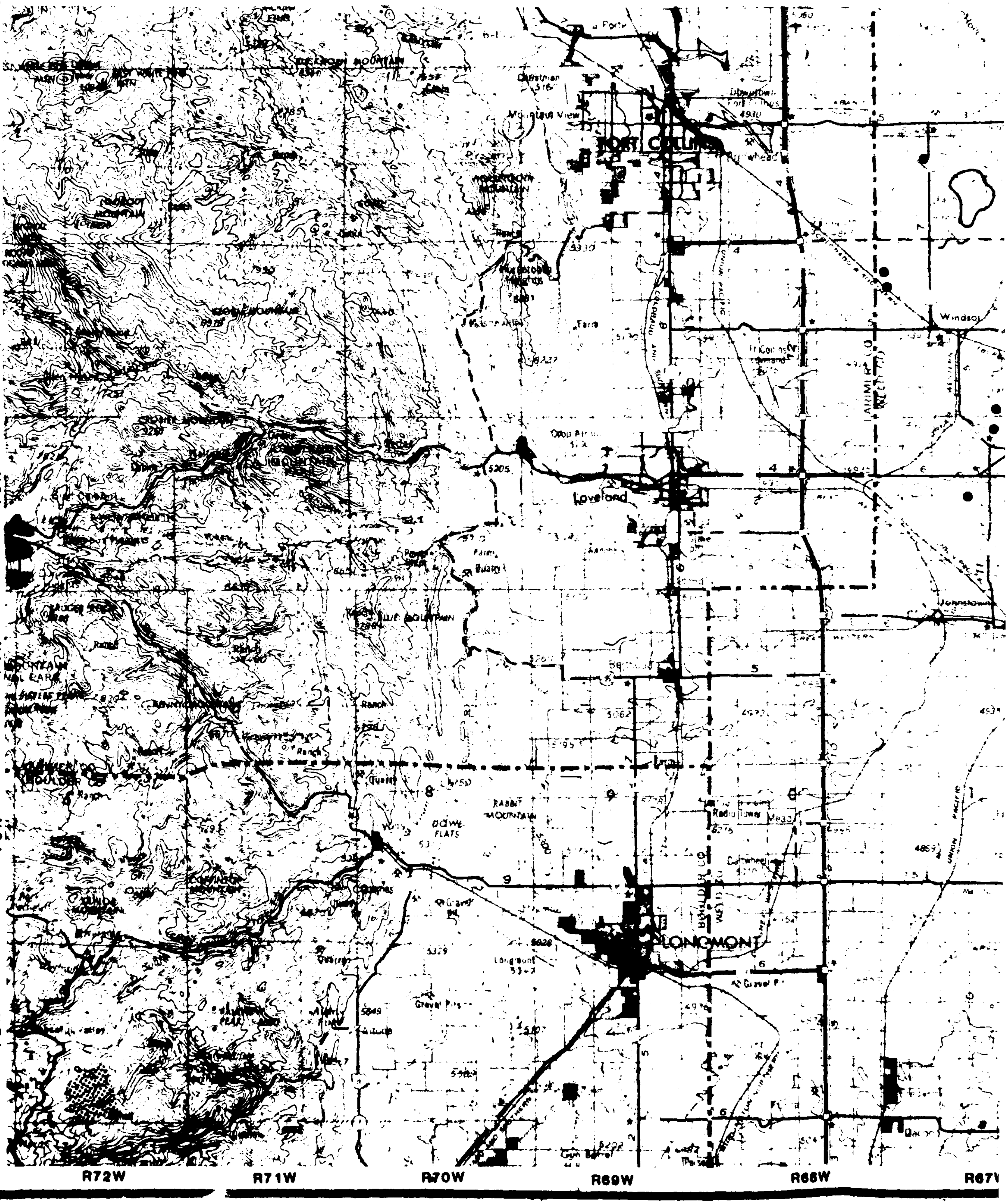
10
CHEYENNE
State Capitol
University of Wyoming Agricultural Experiment Station
LARAMIE COUNTY
WELD CO
SIMPSON MESA
CHALK BLUFFS
Powder Draw
Substation
N CREEK
GROVER
SAND CREEK
EASTMAN
WILDHORSE
SCHLAGEL
KING SOLOMON
Gravel pit



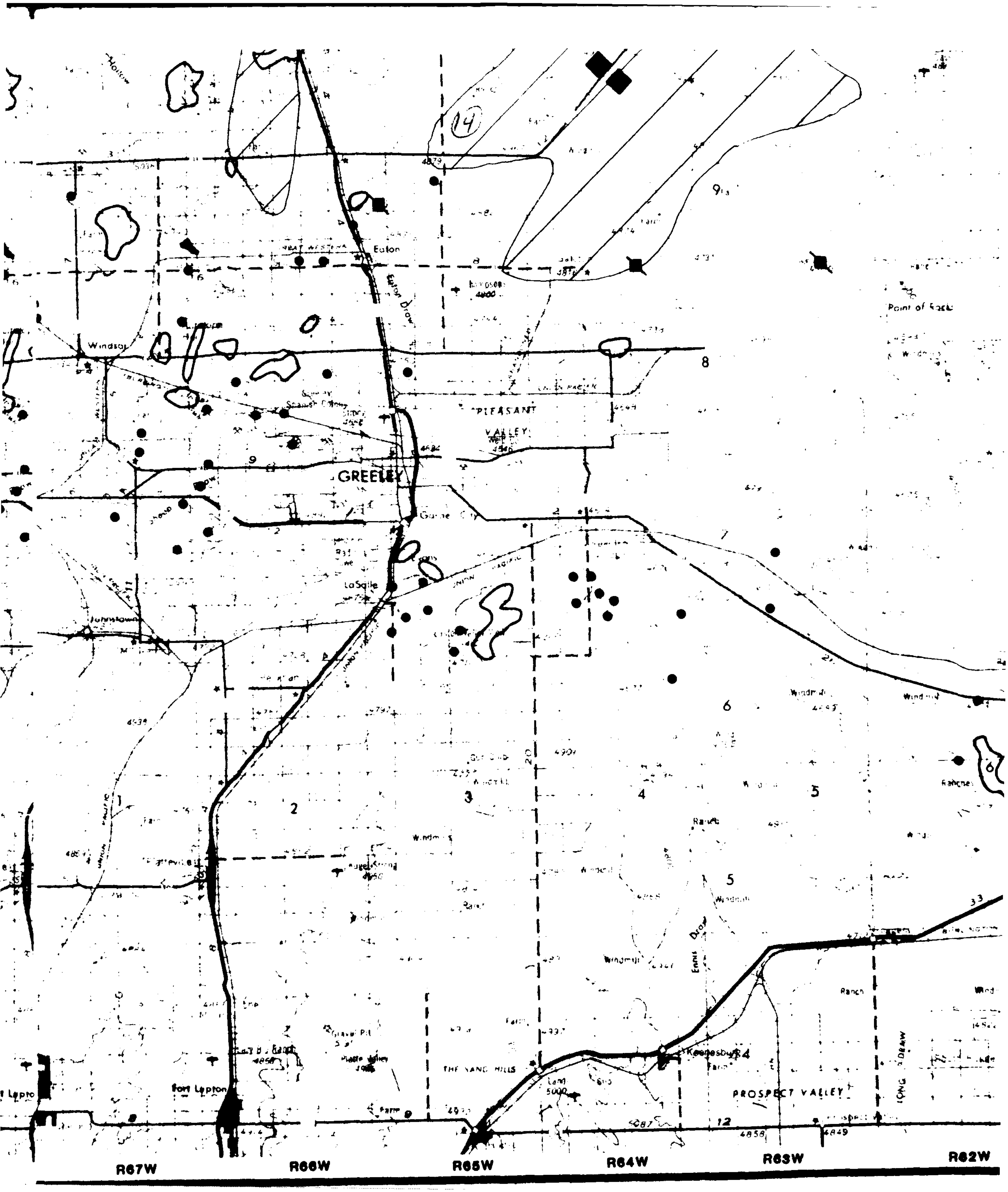
11
Egbert
Bluffs
GROVER
KEOTA
PAWNEE
Radio Tower
Ranch
Farm
Windmill
Oil Wells
Gravel pit
Jackson Draw
SEVEN CROSS HILL
P A W N E E
15

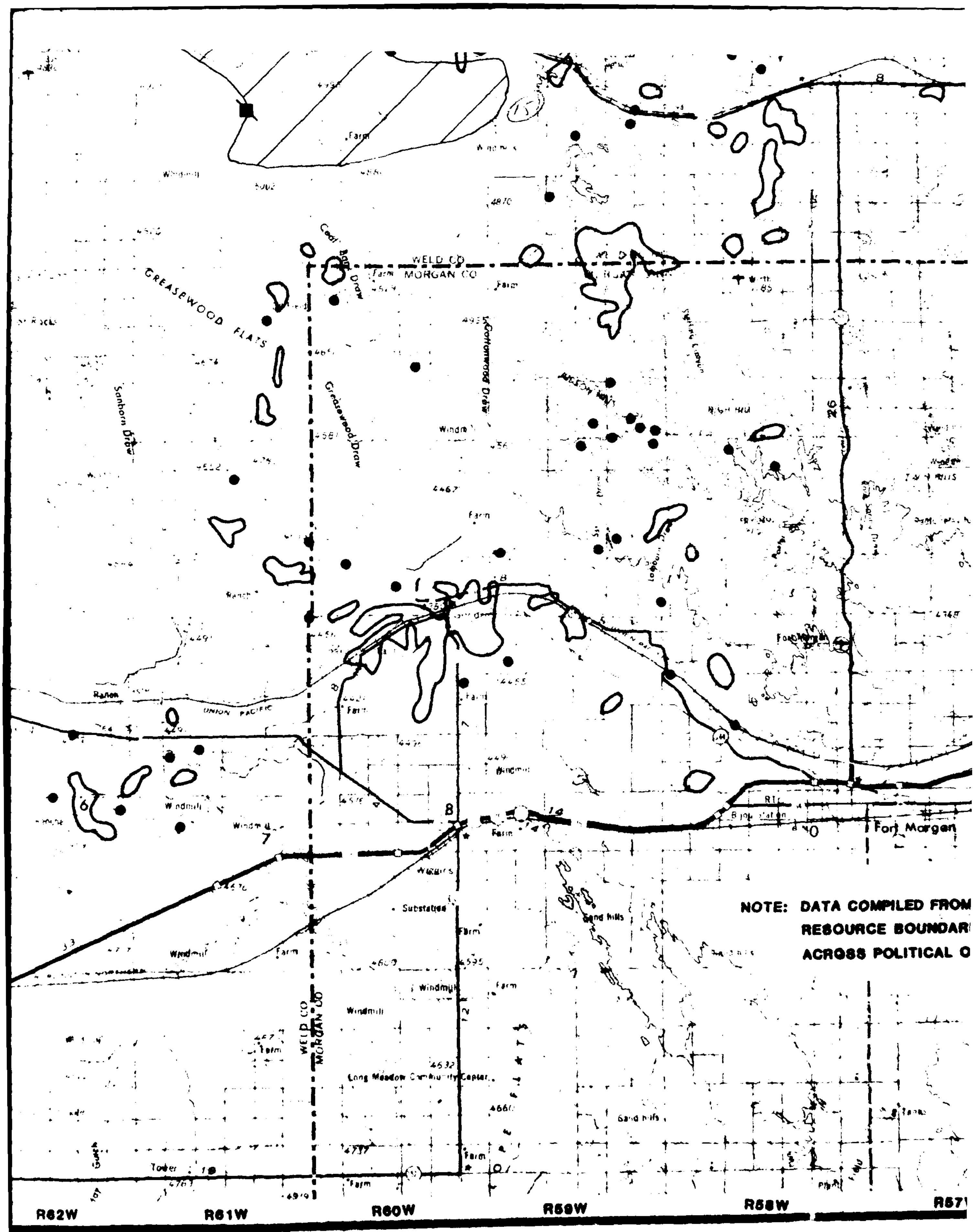


SCALE IN MILES
0
4
8
LEGEND
PRODUCING OIL OR GAS WELL
URANIUM OCCURRENCE
GEOTHERMAL TEST HOLE
OIL OR GAS FIELD, MULTIPLE PRODUCING WELLS, UNCLASSIFIED
X
MINE, PIT, QUARRY
UNDERGROUND MINE, ABANDONED
2
Fe,C
MINERAL OCCURRENCE, AS NOTED, ECONOMIC CLASS 2
Fe
MINERAL OCCURRENCE, UNCLASSIFIED
ECONOMIC CLASSES
1 ECONOMIC RESOURCES
2 MARGINALLY ECONOMIC RESOURCES
3 SUB-ECONOMIC RESOURCES (NONE IDENTIFIED WITHIN THE REGION OF INFLUENCE)
4 HYPOTHETICAL RESOURCES
Gravel pits
Oil wells



NOWN AND POTENTIAL ENERGY AND MINERAL RESOURCES (EXC


14
Eaton
Eaton Draw
Windsor
GREELEY
PLEASANT VALLEY
Garden City
LaSalle
Johnstown
Platteville
Fort Lupton
Keenesburg
PROSPECT VALLEY
THE SAND HILLS
Point of Rocks
LONG DRAW
Ennis Draw
R67W
R66W
R65W
R64W
R63W
R62W



WELD CO
MORGAN CO
GREASEWOOD FLATS
Sanborn Draw
Greasewood Draw
Cottonwood Draw
UNION PACIFIC
Wiggins
Substation
Long Meadow Community Center
Sand hills
Fort Morgan
NOTE: DATA COMPILED FROM
RESOURCE BOUNDARI
ACROSS POLITICAL O
R62W
R61W
R60W
R59W
R58W

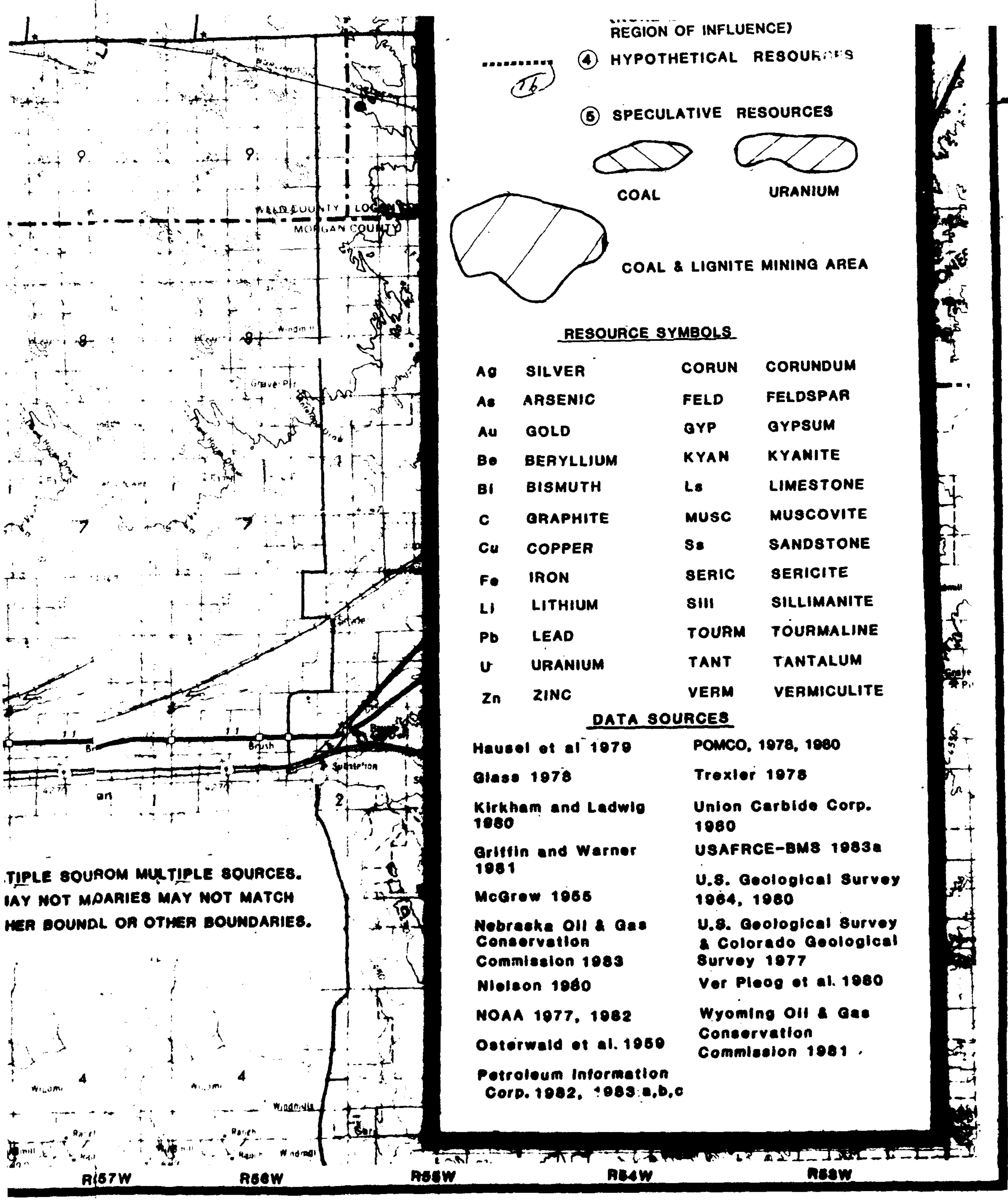


FIGURE NO. 2.6.3-2